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# Algorithm for Pre-Processing Chest-X-Ray using Multi-Level Enhancement Operation

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***Abstract*— Accuracy in diagnostics of life-threatening disease based on chest x-ray images is an atmost importance in healthcare sector, where medical image processing has already played a contributory role from more than a decade. In this regards, image enhancement plays a critical role in exposing more information to the foreground image of clinical importance. We have reviewed the most existing system pertaining to chest image enhancement and found that more enhancements could be done to enhance the signal quality. Therefore, we present a sophisticated algorithm that performs multiple operations for enhancing the chest x-rays. The proposed paper introduces techniques for enhancing chest x-rays using non-linear enhancement, primary enhancement, secondary enhancement algorithms on JSRT database. The proposed system shows better quality of enhanced region in comparison to the most frequently adopted techniques for medical image enhancement.**

***Keywords-Chest X-Rays, Diagnostics, Image Enhancement, Medical Image, PSNR***

## I. INTRODUCTION

In the area of healthcare diagnostics, medical image processing has played a contributory role. From the various ranges of available radiological images generated from ultrasound, x-rays, magnetic Resonance imaging, Computed Tomography, Positron Emission Tomography etc, each has its own method of capturing the images. However, even after narrowing the focus of the image capture, only a few portions of the radiological images are of clinical importance to the consulting physician [1]. But there are various reasons for which the pathologist as well as radiologist believed that image generated by such radiological test doesn't yield 100% accurate information. For less minor forms of the life-threatening disease, such errors may not matter much, but it does potentially matter otherwise. However, exposing the patient to harmful radiological rays are medically not advisable and may be quite an expensive affair for both doctor and patient. Hence, from the past decades usage of image processing is increasingly used to identify the problems and solve it. The first step in such problem identification is to perform image enhancement. As if the image with clinical importance is not enhanced it may potentially lead to outliers in advanced analytics of medical data [2]. Hence, image enhancement plays a crucial role in exposing the disease with more information to the doctor or to the process of further exploration of the disease. This paper discusses about the chest x-ray images and proposed a solution with bigger operation and lower computational cost for enhancing the chest x-rays. The radiological images especially chest x-ray images suffers from following problems i.e. i) multiple silhouette, ii) presence of rib cages (bones), iii) shadows of breast in female subjects, iv) diaphragm etc. Although there are advanced versions of radiological images but chest x-ray image is considered to be primary diagnosis factor by the clinicians. Hence, if the chest x-ray images are shrouded with various artifacts or issues, post-diagnosis will always lead to outliers. Hence, it is necessary that chest x-ray images should be properly pre-processed even before subjecting it to advance analysis. Therefore, this paper presents a very simple and cost effective image enhancement process only for chest x-ray images with multiple operations of enhancements. The paper is organized as follows - Section A highlights present research work carried out in medical enhancement with incorporated problems. Discussion of the proposed system with briefing of its contribution is presented in section B followed by research methodology and its schematic design to accomplish the stated goal of study in section II. Algorithm description is discussed in Section III followed by Section IV that demonstrates the outcomes of the proposed study followed by summary of paper in section V.

### *A. Background*

This section discusses about the studies being carried out by the significant authors pertaining to the medical image enhancement. Liang and Si [3] have presented a unique decomposition mechanism for the medical images that can perform non-linear enhancement with suitable contrast. The focus of the study was to increase the contrast of medical images that are suppressed by the radiological devices and external artifacts. Wen and Qi [4] have used fuzzy logic as well as wavelet-based approach for enhancing the ultrasound images. Various forms of transformed-based techniques are also applied to enhance the contrast. Girdhar et al. [5] have performed image enhancement using segmentation based technique using region of interest. The system calculates the threshold value and enhances the foreground images compared to the background images. Datta et al. [6] have presented a study to enhance the ocular image of retina whose quality is measured using various statistical parameters related to structural similarity. Parasar and Rathod [7] have enhanced the conventional mechanism of independent component analysis. Different from conventional techniques, the authors uses non-Gaussian distribution to perform analysis along with neural network to perform optimization. There are various studies in literatures that have witnessed usage of median filters as a media of enhancing the medical images. Fan et al. [8] uses median filter along with convolution for enhancing the quality of radiological images. Usage of FPGA was seen in the work carried out by Park et al. [9] have developed an idea of mask filter for adaptively enhance the edges of the medical images. The author also uses Laplacian filter for enhancing the image sharpness. Similar direction of the work was witnessed by Jain et al. [10] who have presented a hardware-based approach for median filtering. The prime idea was to develop a reconfigurable hardware filter. Kang et al. [11] have used regression-based technique on the top of median filtering for enhancing the image. The authors have carried out classification using Support Vector Machine. Thakulsukanant and Patanavijit [12] have presented a technique to enhance the resolution of blurry image/video using spatial-based enhancement.

There are various studies being published most recently for chest x-rays e.g. Bhattarai et al. [13] and Zhang et al. [14] using clinical mechanisms. However, such studies are more inclined towards clinical research and less towards computing. Bennet et al. [15] have presented a technique where the authors have used conventional discrete wavelet transforms in order to extract features for disease classification purpose. Iqbal et al. [16] have investigated chest radiological images in order to perform detection of lung nodule. The authors have also worked on the segmentation process for 60 images of lung-related diseases. The outcome of the study was compared with multiple prior works to find that presented work provided better sensitivity and less false positive. However, the limitations will be that the work was emphasized on computed tomography and not on chest x-rays. Moreover, the study didn't present any novel ideas about preprocessing the radiological images. Baz et al. [17] have presented a study for involuntary detection of multiple dimensions of lung nodules from computed tomographies. Sarage and Jamnhorkar [18] have exclusively performed enhancement of chest images using mean and median filters. Similar line of study was also conducted by Assefa et al. [19] using multi-resolution techniques. The enhancement followed by detection is carried out using entropy-based data as well as inverse differential moment and homogeneity. However, none of the studies have actually focused on chest x-rays considering the bigger scenario of problem as well as the existing solution may solve only one set of problem but it is still not able to address multiple variants of problems in one chest x-ray images. Therefore, there is a need of a technique that performs multiple-level of optimization in same platform for one chest x-ray, which is cost-effective in nature. The next section discusses about the problems being identified in the existing system followed by proposed system description.

### *B. The Proposed Solution*

The main goal of the proposed study is to develop a unique algorithm that can perform multiple operations leading to highly enhancement of chest x-ray image to enhance the detection rate of the chest-related disease. Our major aim lies in enhancing the signal quality in order to reduce the outliers when the chest x-ray image is used for analysis by the clinical personnel. It should be noted that presented work is focused on preprocessing the chest x-ray images using multiple ranges of operations. Although, there are various implementations in past pertaining to image enhancement, but we bring out contribution / novelty by setting the following research objectives that have been addressed in this manuscript:

- *Capability to Process Chest X-Ray Image:* Chest x-ray images are normally associated with complexities (poor illumination, presence of radio-opaque objects) and the proposed system is designed to perform enhancement using 3 different enhancement operations.
- *Cost-Effective Image Enhancement:* The proposed system doesn't store any run time values and responds faster with highest signal quality that leads to its enhance capability to process many complex chest x-ray images.
- *Multi-Level Enhancement:* The technique applies enhancement of the chest x-rays using multiple statistical variables that can potentially control the image resolution to a higher degree.

## II. RESEARCH METHODOLOGY

The proposed system considers analytical research methodology, where multiple techniques have been presented in order to ensure the effectiveness of its outcomes. The adopted scheme of implementation is shown in Fig.1, according to which the proposed system takes the input as a chest x-ray image, which after processing will give enhanced image as an output.

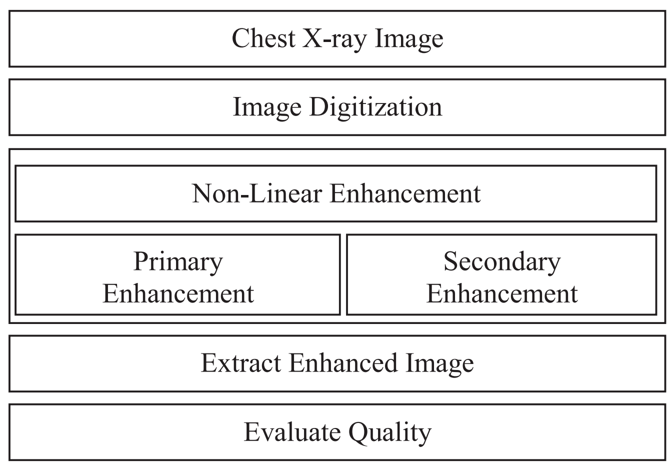


Fig. 1. Adopted Scheme of Research Methodology

The effectiveness of the outcome image will be scaled using peak signal-to-noise ratio. The first phase of the processing will include digitization followed by contrast enhancement using non-linear filtering. The proposed mechanism also support primary and secondary forms of image enhancement which performs enhancements of the pixels data based on Gaussian distribution. This mechanism significantly performs improvement to contrast, brightness, sharpness, and potentially restores good amount of data quality. An iterative form of experiments and evaluation has been performed for analyzing the visual and numerical outcomes of the proposed system. One or other way, the presented system performs an exclusive optimization of the image signal quality that significantly assists in diagnosing a life-threatening lungs diseases.

## III. ALGORITHM IMPLEMENTATION

The development of the algorithm is carried out using chest x-ray image from JSRT datasets [20]. In chest x-ray, black portion of the image represents air, gray portion represents fat, and lighter version of grey colors represents soft tissues, while dense white color represents either bone or some potentially opaque objects. Feasibility of incorporations of non-linearities in luminance components over chest x-ray is quite high and can easily leads to degradation in the diagnostics process. The first algorithm is non-linear filtering process that considers the input image and enhances its precision to double (line-1). The array dimension for the maximized size of image I is mapped in two matrices viz. nr and nc (line-2). We develop a shifting parameter using line-3 which is used for comparison in line-6 and line-7. The comparison in line-6 is carried out for horizontal step while that of line-7 is carried out for vertical step. Finally, the shift parameter is updated using line-9 that leads to generation of enhanced image Ienh using 3 iterations of image enhancement. Such iterations parameters can differ from one to other image thereby giving higher degree of flexibility in presented non-linear enhancement.

**Algorithm for non-linear enhancement**
**Input:** *I* (input image)
**Output:** $I_{enh}$ (enhanced image)
**Start**
1. I=double(I)
2. [nr, nc]=size(max(I))
3. $sh=2^{(\log2(\min(nr, nc)))-1}$
4. while (abs(sh)> 1)
5. for i=1:nIter
6. compare (0, sh)
7. compare(sh, 0)
8. end
9. sh=-sh/2
10. get $I_{enh}$

**End**

The second algorithm is responsible for carrying out the primary enhancement of the chest x-ray. For this purpose, the algorithm initially considers performing distribution of image data in the ith band of spectrum. We use the similar principle (like in our prior algorithm line-2) to get matrices m and n, which we use in nested loop in Line-2 and 3. We use a simple distribution function where k1 is determined by double integration of recently processed image function of F(x, y) to be equated to one. The variable var is the variance and is considered as a form of constant. Finally, in order to accomplish a superior form of enhanced image, we apply logarithmic difference of digitized image and convolved image with respect to function s. Owing to incorporations of the convolutions of the image, the algorithm can actually accomplish better contrast in the primary enhancement level itself.

**Algorithm for Primary Enhancement (Sharpening, color uniformity, etc)**
**Input:** *I* (input image), var (variance)
**Output:** $I_{enh}$ (enhanced image)
**Start**
1. init I,
2. for i=1:m
3. for j=1:n
4. $s(i,j)=k1*\exp(-(i^2+j^2)/var^2)$ //k1=1
5. End
6. End
7. $I_{enh}$=log(I+1)-log(convolution(I+1), s))

**End**

The secondary algorithm performs the enhancement of the primary enhancement technique. The algorithm takes the input image and assigns a weight W and variance var. The matrix W will consists of further initialize two sub-weights e=0.8 and f=0.2. Similarly, the variance matrix var will consists of two sub-variance components i.e. e1=270 and f1=50. The algorithm resizes the digitized input image to half of its original dimension to generate width w and height h as shown in line 4. We develop a nest loop in line-5 and 6 to generate width relations wrel matrix in line-9 and similarly generate height relation hrel in line-18. We also find the final relation R for both width and height in line-10 and line-19. This will result in generation of enhanced image, which is re-subjected to the previous algorithm of primary enhancement.

**Algorithm for Secondary Enhancement (Color Restoration)**
**Input:** *I* (input image), W (weight), var (variance)
**Output:** $I_{enh}$ (enhanced image)
**Start**
1. init W=[e f] and var=[e1 f1]
2. If (e==0.8 && f=0.2 && e1=270 && f1=50)
3. [m, n]=size(I)
4. w=m/2, h=m/2
5. while w>1
6. for i=1:m
7. for j=1:n
8. if (i+w)<m
9. $w_{rel}$=log(I(i+w, j))-log(I(i,j))
10. R(i,j)=R(i,j)-$w_{rel}$ & R(i+w,j)=R(i+w,j)+$w_{rel}$ //R=zero(m, n)
11. End
12. End
13. End
14. while h>1(h=n/2)
15. for i=1:m
16. for j=1:n
17. if (j+h)<=n
18. $h_{rel}$=log(I(i,j+h))-log(I(i,j));
19. R(i,j+h)=R(i,j+h)+$h_{rel}$ & R(i,j)=R(i,j)-$h_{rel}$
20 for i=1:m
21. for j=1:n
22. R(i,j)=(R(i,j)-Min)*255/(Max-Min);
23. Apply Algorithm for Primary Enhancement
24. get $I_{enh}$

25. End
**End**

The entire above stated algorithm works in individual manner with no much inter-dependency on each other. Such forms of autonomous algorithm suite are developed in order to give higher degree of flexibility to the attending doctor for carrying out a precise diagnostics. A closer look into the algorithm will show that a simple matrix-based computation process is introduced and with size of the matrix being almost constant that results in no increment in storage size. This design process further results in faster access and process even for a massive number of the chest x-ray dataset. The algorithm performs multiple level of chest x-ray enhancement by altering the weight and variance factor. The algorithm explores the significant features of the input image implicated with adaptive histogram equalization. We also investigate the PSNR(Peak Signal to Noise Ratio) of the image along with implementing the algorithms stated above.. This step assists in consolidating the masses of the cancer tissue or tumor in the chest from the x-ray image. The next section discusses about the visual and numerical outcomes accomplished after implementing the proposed study.

## IV. RESULT AND DISCUSSION

This section discusses about the outcomes being accomplished from the presented study. In order to perform an analysis, we consider testing with JSRT database [20]. For evaluating the impact of the proposed study, we consider variable sizes of the dataset images of chest x-rays where the outcome of the study is tested with respect to peak signal to noise ratio. However, we will discuss in this section both visual outcomes and numerical outcomes accomplished from the study.

### A. *Visual Outcomes*

This section will discuss the visual outcomes accomplished from the proposed study after being tested with various dependenble variables. Fig.2 shows the visual outcomes.

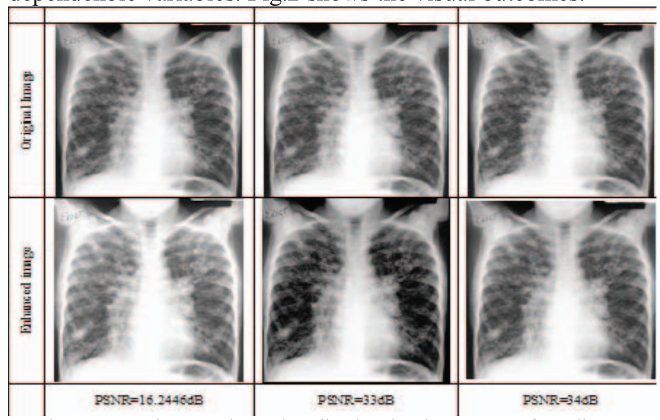


Fig.2. Images in second row describe the visual outcomes of Nonlinear, Primary and Secondary Enhancement algorithms respectively.

### B. *Numerical Outcomes*

In order to scale the effectiveness of the proposed system, we consider the most frequently used image enhancement techniques using median filters. The prime reason for selecting this work for comparative analysis is because the author have implemented frequently used median filter for retention of best visual quality that are damaged or adversely affected by maximized impulse noise. Considering the testing with around 550 medical images, we capture the respective PSNR on best 10 samples of chest x-ray image to fit in this manuscript, whose outcome is shown in Table.1.

Table. 1. Comparative Analysis

| | **Median Filter** | | | | **PSNR of Secondary Enhancement Algorithm** |
|---|---|---|---|---|---|
| | noise=0.1 | noise=0.5 | noise=0.9 | **Avg. PSNR of Existing Approach** | |
| Sample-1 | 29.65 | 12.76 | 6.782 | 16.397 | 36.834 |
| Sample-2 | 33.25 | 15.54 | 7.541 | 18.777 | 39.112 |
| Sample-3 | 31.86 | 13.88 | 5.366 | 17.035 | 36.775 |
| Sample-4 | 32.19 | 15.99 | 7.021 | 18.400 | 38.954 |
| Sample-5 | 30.17 | 16.74 | 4.528 | 17.146 | 37.411 |
| Sample-6 | 32.15 | 18.65 | 10.034 | 20.278 | 36.878 |
| Sample-7 | 31.76 | 17.22 | 8.551 | 19.177 | 37.318 |
| Sample-8 | 30.27 | 16.65 | 9.389 | 18.770 | 38.598 |
| Sample-9 | 32.16 | 17.83 | 7.061 | 19.017 | 37.016 |
| Sample-10 | 31.76 | 13.02 | 17.676 | 20.819 | 37.385 |
| Total | 315.22 | 158.28 | 83.949 | 185.816 | 376.281 |
| Avg | 31.522 | 15.828 | 8.3949 | 18.582 | 37.6281 |

The outcome shows that the proposed system has achieved approximately 37.62 dB of PSNR while the existing technique of frequently used median filter-based image enhancement is found to be nearly 18.582 dB of PSNR. This outcome will eventually mean that proposed system is found to enhance the signal quality by 12% without using median filter. The prime reason behind it is usage of median filters is comparatively expensive owing to compulsory sorting stage of neighboring pixel that degrades the performance of quality significantly. However, proposed technique offers multiple levels of image enhancement and is relative cost effective as it can enhance only the region of clinical interest and not the entire image to improve the detection of disease with more accuracy.

## V. CONCLUSION

This paper discusses about a unique technique of chest x-ray image enhancement where the enhancement is carried out using multiple ranges of operation. We develop a very simple concept that image with maximized contrastive density may posses susceptible cancerous part, which should be identified higher accuracy. For an efficient analysis, we perform an extensive experiment with various numbers of images, altering the research various of weight, variance, correction factor, etc and monitoring the outcomes. We also stressed on accomplishing better PSNR values even in comparison to the most frequently used median filters in medical image processing. Our future work will be to extend this model for segmentation.

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