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Comparative Analysis of Image Enhancement Techniques for Chest X-ray Images

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***Abstract*—X-ray radiography plays a crucial part in diagnosis of various diseases in human body like Covid-19, Cancer and Pneumonia. The images obtained through X-ray radiography is interpreted by Surgeons, Pathologists and Radiologists for detecting anomaly in scanned body part. Chest X-ray is one of the cheapest and easily accessible tests of functioning of chest and lungs. However, images obtained through X-ray are not very clear, low in contrast and with lesser variation in gray level. Image enhancement is done for better visualization of images and bringing forward the underlying details of image. The Kaggle repository of total 6334 chest X-ray images were used for experimentation and calculation works. In this paper, we have compared various combinations of contrast enhancement techniques such as CLAHE, Morphological operations (black and white hat transforms) and noise reduction techniques like Median filter, DCT and DWT. The Comparison was done on the basis of image quality assessment parameters such as MSE, PSNR, and AMBE. The results showed that fusion of CLAHE and DWT techniques gave best results with highest PSNR value and lowest AMBE among the various models discussed. The proposed methodology shall be very helpful in diagnosis of diseases from chest X-ray images.**

Keywords—**Medical images, Chest X-rays, Contrast Enhancement, Noise Reduction, Image assessment parameters**

I. Introduction

Clinical images are obtained through medical devices like Computerised tomography (CT), X-ray machine and Ultrasound machine. Images obtained through these devices are not very clear and important details are hidden within. Repositories of images are available freely available on internet, people from different field carry out research work on these datasets for image enhancement thus helping doctor and other medical fraternity in diagnosis of diseases resulting in betterment of society.X-rays are particularly helpful in detecting pathology in bone structures and also in soft tissues like muscles. Light or dark spots, lines, fogging, particles, and other "artefacts" can appear on a diagnostic X-ray image. Dilapidation occurs during the capturing of X-ray images due to lighting in X-ray room, position of back plate etc. The application of image restoration can help to improve such dilapidation.

The primary goal of the digital image processing (DIP) method is to get better illustrative information for human interpretation. It includes the contrast modification, sharpening, filtering, noise reduction etc. Filtering of images is the greatest augmentation for removing additional noise from the image. It is also used for image smoothening and sharpening. When employing the local augmentation technique to enhance an image, the image's mean intensity may be lost, and the computing time is long as well. Histogram equalization technique is one of the most popular image processing techniques, available for improving the quality of X-ray images. There are still times when using a uniform histogram to enhance an image isn't the greatest option. As a result, various histogram approaches, such as adaptive histogram equalisation, may be required. The downside of adaptive histogram equalisation is that it enhances not only the image, but also increases the noise in the image. As a result, many image enhancing techniques are still experimental and require participatory procedures to achieve excellent output. This study includes 5 sections where section 2 deals with existing works, section 3 deals with methods and techniques, experimental result are included in section 4 and conclusion in section 5.

II. RELATED WORKS

R.Y. Huang et al. [1] presented a method for contrast enhancing and noise removal based upon CLAHE and bilateral filtering. W. Rui et al. [2] applied the TV - homomorphic filter, which played a role for balancing the brightness and enhancing the information details. Y. Singh et al. [3] used three-enhancement techniques i.e., HE, AHE, CLAHE and worked on the performance using various parameters as PSNR, SNR, MSE. Attia et al [4] worked on the 8Chest X-ray images of low quality and applied 3-major techniques of enhancing and used PSNR, MSE, MAXERR, L2rat for comparison of results. Lester Grover et al. [5] worked on chest x-ray data of 254 adults with heart diseases, patients were divided into small groups, cardiothoracic ratio gave 70% accuracy. Ginneken BVet al. [6] developed a neuro-Fuzzy system for obtaining the clear output of image, where HE provided the better result. Rahmi-Fajrin et al. [7] have worked on the dental image quality improvement for capping treatment, and applied the CT, CS, CLAHE methodology and evaluated based on PSNR. Mohd-Isa et al. [8] applied CLAHE for the enhancement of digitized X-ray films, where the good value 31db – 32db is provided for CLAHE and MMCLAHE.

TABLE I. RADIOGRAPHIC IMAGES WORK WITH TECHNOLOGY

Data Image Type	**Reference**	**Methodology**
Bone X-ray images	S.U. Khan et al. [9]	Applied Wiener filter and DWT filter
	Y. Zhang et al. [10]	Used fruit fly optimization algorithm
	Huang et al. [1]	Bilateral filtering and Adaptive Filtering
Dental X-ray images	S.A.Ahmad et al. [11]	AHE, SCLAHE, CLAHE, MAHE
	J. Naam et al. [12]	MMG (Multiple Morphological Gradient)
	T.T Ngan et al. [13]	Affinity propagation Clustering & Fuzzy Aggregation Operator
Chest X-ray images	Z.Xueet al. [14]	Histogram of oriented Gradient & contour-based shape descriptor
	S.Chen et al. [15]	2-scale retinax with various weighted factors
	R.Senthilkumar et al. [16]	Comparison of CLAHE, AHE and histogram equalization

Detection of disease in living being is very important for timely precautions and treatment of health condition. Combination of techniques used resulted in enhancement of images [10]. X-rays gives one of the best results at cheaper cost as compared to other radiographic test, however, image clarity is very poor and thus requires enhancement [13].

III. METHODOLOGIES

This paper focuses on enhancement of chest X-rays images. X-rays are electromagnetic waves, when passed through body create images based upon its penetration through various parts like bones and soft tissues like muscles. X-ray images are gray level images. These are the images with low contrast and high level of noises.

A. Dataset

A Kaggle repository [17], comprising of radiographic medical images i.e., Chest X-ray of total 6334 Covid positive patients is used. This dataset has been prepared by the biomedical researchers from various hospitals and research centres. All the images are labelled by the experienced radiologist's panel. Chest X-ray is low-cost diagnostic method however visibility quality of images is very poor as compared to other radiography images like MRI and CT scan. In poor countries where high accuracy clinical devices are not available, X-rays images are quite helpful in diagnosis. Therefore, chest X-ray images have high scope of improvement.

B. Flowchart

The presented below flow charts highlights the proposed approach of the work. For the input image i.e. chest X-ray, image histogram was obtained, thereafter combination of various image enhancement techniques like CLAHE, morphological operators(only black and white transforms used), median filter, DCT and DWT were used. Image histogram for each hybrid technique was obtained.

The enhanced image obtained through various techniques were evaluated based upon image quality assessment parameters such as Mean square error (MSE), Root Mean square error (RMSE), Absolute mean brightness error (AMBE) and Peak signal to noise ratio (PSNR). Accordingly, the combination of techniques with best set of parameters was recommended for the future work on diagnosis of diseases.

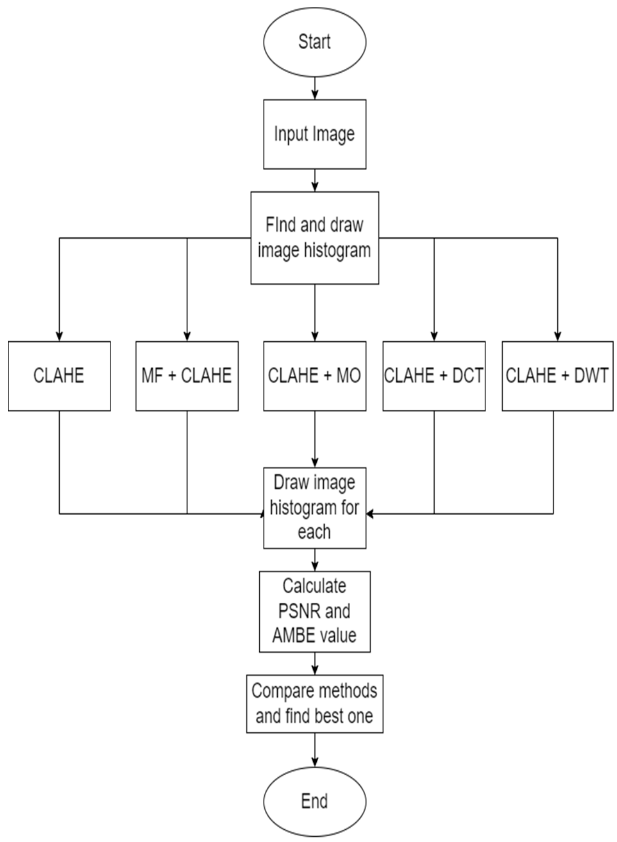

Fig.1. Proposed Approach

C. Histogram based Contrast Enhancement Techniques

Histogram Equalization: Histogram equalization is one the simplest and popular method for contrast enhancement as the pre-processing step of image enhancement. It is the useful technique especially when the intensity values of images are limited to small range. Through this technique intensity level can be distributed on the whole range of histogram. It results in increase of contrast level in lower contrast areas of image. This method is very helpful in medical field image like thermal images, X-rays. Histogram equalization improves the visibility of intrinsic details of chest X-ray images. However, this method increases the noise level of image by distributing the intensity level.

Contrast Limited Adaptive Histogram Equalization (CLAHE): Histogram equalization uses the same method to transform the whole image, distributing pixels on whole range thus increasing noise level. Over-brightness of image leads to loss of important details of image. CLAHE is upgraded form of histogram equalization which was initially built for enhancing the radiography process in ship industry; however, it became successful for enhancement of low contrast images like X-rays in medical field as well.

In CLAHE, first of all, image is divided into small tiles (default size 8*8), contrast limiting is applied on each tile above threshold value (default clipping limit value 40), pixel values above threshold are uniformly distributed in neighborhood areas, thereafter bilinear interpolation is used to combine neighborhood tiles. CLAHE uses the cumulative distribution function (CDF). CLAHE gives better results in comparison to ordinary histogram equalization techniques in terms of lesser brightness level and noise.

D. Morphological Operators

The Morphology is a useful technique for representing and defining the shape of a region, such as its borders. It is based upon set theory. Mathematical operations like reflection, translation and difference can be performed on two sets i.e. A and B. Set A is image element. Set B is structuring element. Various type of morphological operators is dilation, erosion, opening, gradient, closing, black and white Hat. Erosion and Dilation are opposite in nature which removes & expands front object in image. Opening and closing are based upon order of Dilation and Erosion.

Top hat extracts only bright parts of image on dark background whereas Bottom hat extracts dark features of image on light background. Top hat and bottom hats are also known as white and black hat respectively. White and black hat gives better result for gray level images. For contrast enhancement of gray level images, only white hat and black hat morphological operators are required.

To obtain enhanced image using morphological operators, first of all, individually obtain the white hat and black hat transforms of input image. Thereafter, perform addition operation on input image and white hat transform. Subtract the black hat transform from resultant obtained in previous step to get the enhanced image. Equation is as:

$$F = I + W - B \tag{1}$$

Where,

I denote Input Image

W denote White hat transform

B denote Black hat transform

F denote Enhanced Image

E. Noise Reduction Techniques

It is defined as the process of removing noise from a signal. It is generally used for audio and images. When we talk about x-ray images, we could have some noise during the process. It can be worthwhile to decrease or eliminate the noise in our image before proceeding with image improvement. We will discuss three filters in this section: the median filter, the DCT filter and the DWT filter.

Median Filter: Median filter is one of the simplest techniques for noise reduction. The filter is run through each part of image data. For our experimentation we have chosen default box of 5X5 for noise reduction in image.

Discrete Cosine Transform (DCT) Filter: A DCT based filter decomposes a signal into a sum of cosines function, similar to how a Fourier transformation that breaks down a signal into frequencies. It is the most popular data compression method. We need to understand that an image can be decomposed into signal with two-dimension signal. The x-axis signal as well as y-axis signal aims to decompose each signal of output of our image. If a signal has an anomalous value at one location (noise), we attempt to breakdown the signal in order to locate the signal's core. Finally, by employing DCT's inverse function as a result, we get an image that resembles the original but does not contain any anomalous numbers.

Discrete Wavelet Transform (DWT) Filter: The discrete wavelet Transform (DWT) is a wavelet transform that samples data at short intervals. DWT simultaneously provides visual information in the temporal and frequency domains. Wavelet transforms are generally used to reduce noise in images.

F. Image Quality Assessment parameters

This section deals with the metrics to calculate the performance of various techniques implemented on input image. Various parameters like Mean Square Error (MSE), Peak-Signal to Noise Ratio (PSNR), and Average Mean Brightness Error (AMBE) are discussed below:

MSE (Mean Square Error): The MSE is calculated as the cumulative squared error between the original image and enhanced image. MSE is given by:

$$MSE = \frac{\sum_{M,N}[\mathrm{I(m,n)}-\mathrm{O(m,n)}]^2}{\mathrm{M*N}} \qquad (2)$$

Where,

M denotes number of rows.

N denotes number of columns.

PSNR (Peak-Signal to Noise Ratio): The PSNR calculates the peak signal-to-noise ratio, in decibels, between the input image and enhanced image. It is quality measurement tool and its value is derived from MSE. PSNR denotes the evaluation of the peak error.
PSNR is given by:

$$\mathrm{PSNR} = 10 * \log_{10}\left(\frac{R^2}{MSE}\right) \qquad (3)$$

Where,

MSE denotes Mean square error.

For our application R is 255(8-bit unsigned integer data type) and it denotes the maximum fluctuations in data type of input image

AMBE (Average Mean Brightness Error): The AMBE is calculated as the difference between the average intensity of the input image and enhanced image. AMBE expression is as:

$$\mathrm{AMBE} = |\, \mathrm{I(x)} - \mathrm{I(y)}\, | \qquad (4)$$

Where,

I(x) denotes average intensity of input image.

I(y) denotes average intensity of enhanced image.

IV. EXPERIMENTATIONS AND RESULTS

The implementation work has been carried in PYTHON Programming language and used Jupyter Notebook on Kaggle platform. 10 images were random selected from Kaggle repository of total 6334 images. Above discussed techniques were implemented in hybrid form. Following combinations were implemented on selected image:

- Contrast Limited Adaptive Histogram Equalization (CLAHE)
- CLAHE and noise reduction using median filter(MF)
- CLAHE followed by smoothing through morphological operators (MO)
-
- CLAHE followed by noise reduction technique, based on Discreet cosine Transform (DCT)
- CLAHE followed by noise reduction technique, based on Discreet wavelet Transform (DWT)

The outcome of hybrid techniques is compared with each other and original image. Comparison is presented here in form of image and corresponding histogram:

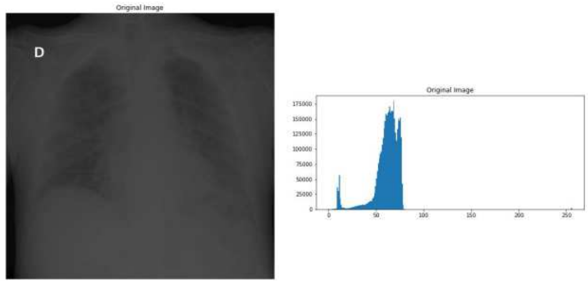

Fig. 2a. Original image

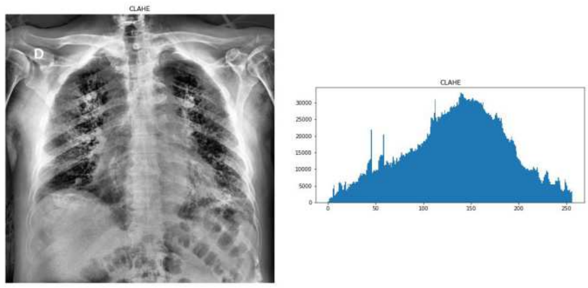

Fig. 2b CLAHE

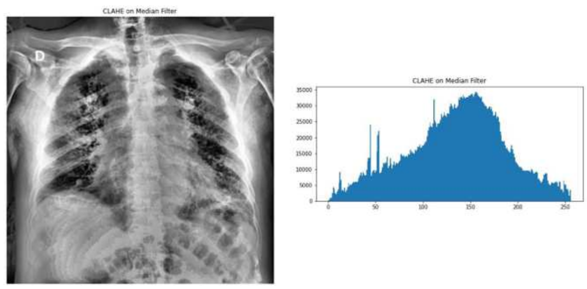

Fig. 2c CLAHE + MF

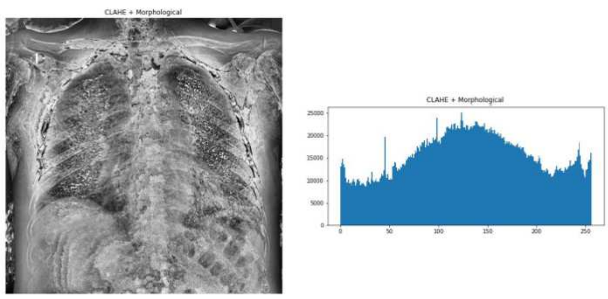

Fig. 2d CLAHE + MO

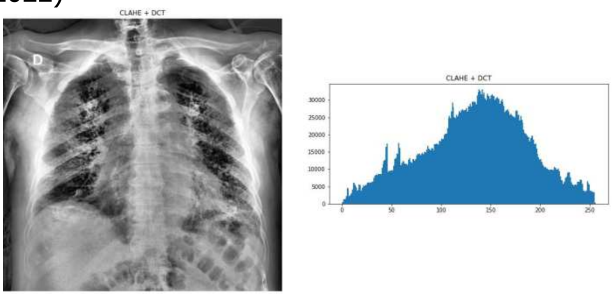

Fig. 2e CLAHE +DCT

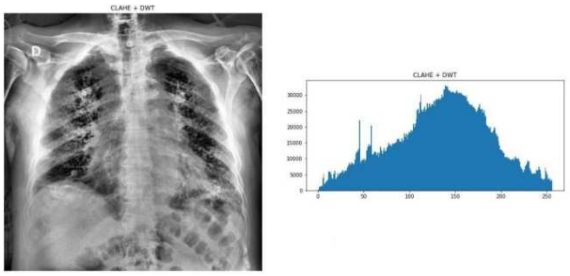

Fig. 2f. CLAHE +DWT (proposed method)

For each hybrid technique, enhanced image and its corresponding histogram diagram has been shown in Figure (2a) to Figure (2f).

To assess the quality of output image, performance metrics such as MSE, PSNR and AMBE were evaluated for each hybrid techniques separately. Performance metrics results are tabulated as:

TABLE II. PERFORMANCE METRICS MATRIX

Techniques used	MSE	PSNR (dB)	AMBE
CLAHE	106.85	27.84	19.23
MF + CLAHE	118.98	27.38	21.40
CLAHE + MO	97.25	28.25	16.79
CLAHE+ DCT	90.19	28.58	14.03
CLAHE+DWT	71.05	29.62	10.61

After analysing the values in the tables and also visually observing the enhanced images, it is clear that best results are obtained in hybrid technique CLAHE+ DWT (proposed method). Hence, CLAHE+DWT gave best results in both qualitative and quantitative assessment.

The proposed combination of techniques i.e Contrast enhancement **using Contrast Limited Adaptive Histogram Equalization** (CLAHE) and noise reduction using **Discreet Wavelet Transform** (DWT) provided the promising results with lowest MSE (71.05), highest PSNR value (29.62) and lowest AMBE value (10.61) among all the hybrid techniques discussed. Results showed the improvement in quality of image as compared to original image.

V. CONCLUSIONS

Image enhancement improves the visual quality of image and helps the clinician in his decision and saves the patient's lives. This paper discussed various hybrid enhancement methods for improvement of chest X-rays visualization by reducing the uneven illumination and enhancing the quality of image.

In this paper, we conclude that CLAHE followed by noise reduction technique, based on Discreet Wavelet Transform (DWT) gave best results as compared to other existing methods. Hybrid combination of contrast enhancement techniques and noise reduction techniques provides the better visualization and are very helpful in removing the limitations faced by individual techniques. The proposed method not only enhanced the contrast of original image but also reduced the noise level of image. Thus, the proposed method can serve as the initial steps for diagnostic of chest diseases such as COVID -19 and Pneumonia from chest X-ray images.

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