

## CONTRAST LIMITED ADAPTIVE HISTOGRAM EQUALISATION WITH EDGE ENHANCEMENT FOR MEDICAL X-RAY IMAGES

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### ABSTRACT

Medical images are one of the most important and elementary images, as their usage is in a very sensitive field i.e., the medical field. The raw data got from medical acquisition devices may have a comparatively poor image quality and may be destroyed due to several types of noises. Detection and extraction of information from these poor quality images is very difficult. Thus such images have to undergo a process called image enhancement (IE). The various enhancement techniques aim to improve the visual aspects of an image. The study has been performed on X-Ray images obtained from SKAN-DR machine. For compliance with medical standards and to fulfill the requirements of digital medical images, the images have been enhanced. The aim of this study is to understand how to improve the image quality, enhance features and gain better characteristics of medical images for a right diagnosis.

The technique proposed in this paper begins with the application of a median filter, for removing noise on images followed by application of Contrast Limited Adaptive Histogram Equalization (CLAHE), basically to improve the poor contrast and then finally an unsharp mask filter is applied, which is the most commonly used type of sharpening. The proof of concept of the feasibility of this technique was performed through MATLAB software.

For testing purposes, X-Ray images of different sizes and various anatomy were used. Evaluation, by a clinician showed that the visibility of minute structures and details in the enhanced images were much better than the original images and the technique itself does not induce any artifacts or distortion.

**KEYWORDS:** X-Ray, Radiography, Enhancement, CLAHE, Unsharp Mask, Filter, SKAN-DR, MATLAB

### INTRODUCTION

A technique is always required for creating a visual representation of the internal structure of the human body so as to diagnose and treat any abnormalities or diseases. Thus medical imaging is one of the most advanced field of imaging, with new inventions and discoveries happening every day. There are multiple modalities of imaging. Here radiography will be discussed. Radiography was one of the first techniques to be identified when Wilhelm Roentgen took a radiographic image of his wife's hand in 1896. Electromagnetic radiations, like X-Rays (other than visible light), were passed through the human body, in order to view the interior of the body, which can be considered as a non-uniformly composed opaque object. Most X-rays have a wavelength in the range of 0.01 to 10 nanometers, with a frequency range lying between 30 peta-hertz to 30 hexa-hertz ( $3 \times 10^{16}$  Hz to  $3 \times 10^{19}$  Hz) and their energies lying in the range between 100 eV to 100keV. X-rays can be classified into two types, namely hard X-Rays and Soft X-Rays. The radiations with photon energies above 5–10 keV are classified as the former, while those with lower energy are classified as the latter.

Generation principle of X-Rays is required to be understood, especially for its use in the biomedical field or medical imaging field. A metal target, placed in a vacuum tube gets bombarded with high-speed, accelerated electrons. This process produces the required radiations. These are then passed through the patient's body. The radiations that are then received after attenuation or absorption are made to fall on a photographic plate or digital recorder, based on the acquisition system. The output is a radiograph. The object's internal structure is seen as a superimposed 2D representation on the detector. The absorption of the rays by the patient is not uniform and is dependent on the composition, structure and particle density [1]. Patient to patient variation can be seen for the same anatomy or structure.

Digitally acquired images, especially in the medical field require some form of enhancement as visibility of the subtle features of the structure projected in the image is of utmost importance. Also, for future automated image processing [1] of these images, it is necessary that they are enhanced. Automated detection of abnormalities based on image, analysis of the structure and composition of anatomy, automated recognition or segmentation [1-2] based on required anatomy detail can be performed, in the future. In general, the techniques of enhancement can be classified into two. One is the enhancement in spatial domain and the other is the enhancement in the transform domain.

Once the images are obtained, they need to be processed in order to make better diagnosis. Various techniques are discussed in this paper. Skanray U-arm, HF Flat Panel Direct Radiography System is used to acquire the images. It is a digital acquisition system with a CsI flat panel detector, with an intelligent anti-collision system, integrated motion control and a color LCD Display.

In general medical diagnostic techniques are indirect methods where the output images/signals should be analyzed in order to identify the abnormality. The reliability of digital x-rays is very high, hence they are widely used for breast cancer detection. Certified radiologists interpret the output x-ray images. It is important that the radiologists have expert knowledge about the basics and physics of x-ray modelling. Hence human interpretation is subjective in nature and is dependent on expertise of the individual. Also if large number of x-rays is to be interpreted, operator fatigue affects the accuracy of the interpretation. Hence the paradigm has shifted to computer aided analysis of medical x-ray images.

Poor contrast, artifacts and inherent noise in radiographs poses a major challenge in the interpretation of automated X-Ray images [2]. Hence it is necessary to enhance the contrast of the radiographs before performing image segmentation to isolate the region of interest. Though considerable research is done in such areas, contrast enhancement is subjective in nature and is dependent on the nature of the original images, generalized contrast enhancement technique is not yet developed.

## **METHODS**

### **Overview**

There are multiple techniques that are used in image enhancement including various types of filtering, like low pass, high pass, median, sobel edgefiltering; contrast can be enhanced through histogram equalization, adaptive form of it, and various other forms of equalisation. Also the sharpening effect can be obtained by multiple methods like unsharp, highboost filtering, first order and second order derivatives (Laplacian) but the most commonly used method in image processing is the unsharp mask.

The proposed method consists of the following three steps:

Median filtering for reduction of noise,

Contrast Limited Adaptive Histogram Equalization

(CLAHE) for contrast enhancement and

Unsharp Mask filter (UM) for sharpening of edges.

### **Median Filtering**

Median filter: One commonly used enhancement technique is filtering, basically used to eliminate unwanted elements of noise. In addition to that, filtering can also be used to enhance certain details such as edges in the image [1]. Images used in the medical field are usually contaminated by a type of noise called salt and pepper noise. Minute variations in the gray scale is the major cause for this type of noise. Median filtering is a popular technique for enhancing images, in order to remove impulse noises, in such a way that, the image sharpness is not altered. It is one of the most commonly used filtering techniques as it provides excellent noise-reduction abilities. Unlike its counterparts (similar sized linear smoothing filters used by the median filter is less [2]. Here, the median filtering was performed by using an in-built function in MATLAB called 'medfilt2' which is a 2D filtering. The size of the window can be chosen, but smaller the window, fastest the median filtering operation. Every pixels value is compared to its neighbourhood and the pixel replaced by the median value of the number of pixels determined by the window size. It basically finds out whether or not the pixel is a representation of its surroundings.

### **Contrast Limited Adaptive Histogram Equalisation(CLAHE)**

Contrast limited adaptive histogram: It is a technique that is used for improving the local contrast of images. It is a generalization or combination of ordinary histogram equalization and adaptive histogram equalization [4-6-7], the histogram is equalized in blocks with a predefined clip limit in an adaptive manner. It does not operate on the whole image but it works on small areas of the images, named tiles. On each tile it works like ordinary Histogram Equalization (HE). A transform function is derived by applying a contrast limiting procedure for each neighbourhood. This prevents the over-amplification that is introduced because of adaptive histogram equalization (AHE) technique. The contrast amplification in the vicinity of a given pixel value is given by the slope of the transformation function [4]. The slope of the cumulative distribution function (CDF) is proportional to the above and therefore to the value of the histogram at that pixel value. CLAHE limits the amplification by clipping the histogram at a predefined value before computing the CDF. This limits the slope of the CDF and therefore of the transformation function. The value at which the histogram is clipped, the so-called clip limit, depends on the normalization of the histogram and thereby on the size of the neighbourhood region. It is advantageous not to discard the part of the histogram that exceeds the clip limit but to redistribute it equally among all histogram bins.

This is performed on MATLAB, again with an inbuilt function called 'adap this teq'. The clip limit, number of tiles, number of bins, distribution parameter need to be specified. Value for each parameter was determined by multiple experiments, for each anatomy as the clip limit is anatomy dependent. The contrast of each tile is enhanced, so that the output image's histogram looks similar to the histogram determined by the 'Distribution' parameter [4]. Through bilinear interpolation the adjacent tiles are combined in order to eliminate the boundaries induced artificially. Amplification of any unwanted regions or information is eliminated by using this method of histogram clipping. By reducing enhancement of contrast in homogeneous areas, the problems related to both the types of equalization (HE and AHE) can be limited. The histogram is clipped based on the defined clip limit and the pixels that have been clipped are then redistributed equally over the entire histogram in order to maintain the histogram count.

## Unsharp Mask

Unsharp mask filter for edges sharpening: Filtering using the unsharp mask is a simple process. It basically enhances the edges and also enhances components of high frequency present in the image. An unsharp or smoothed version [5] of the image is subtracted from the original image and then again added to input image.

Here the application of the unsharp mask after median filtering and CLAHE is basically to remove any noise parameter remaining after the above two processes and to enhance the edges and make them appear sharper. First, a blurred version of the original image is obtained, and this is subtracted from the original image [5]. Thus only the low frequency components get cancelled. The subtracted mask is then added to the original image. This is carried out by applying a low-pass filter, in this case a Gaussian blur algorithm using a small radius was used. The radius of blurring was determined by trial and error, again, an anatomy dependent value. The blurred form of the image is then pixel deducted from the original image and so it is obtained the high pass component. The two steps for the unsharp mask filter that is done automatically by the inbuilt MATLAB function 'imsharpen' are mentioned below:

It first creates a Gaussian mask of required radius and convolves it with the original image so as to blur it.

$$I_{BLUR} = I * G_{mask} \quad (5)$$

Where,

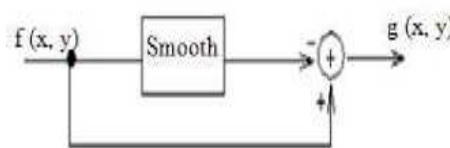
$I$  is the original image,  $G_{mask}$  is the Gaussian blur mask (Gaussian blur algorithm) as shown in Figure 1.

The blurred image is now subtracted from the original image to enhance only the edge features. It is then added backwards to the original image to get the output image [5].

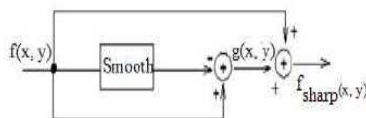
This function is represented as follows:

$$I_{edge} = (I - I_{BLUR}) \quad (6)$$

$$I_{output} = I + I_{edge} \quad (7)$$



**Figure 1: Spatial Sharpening**



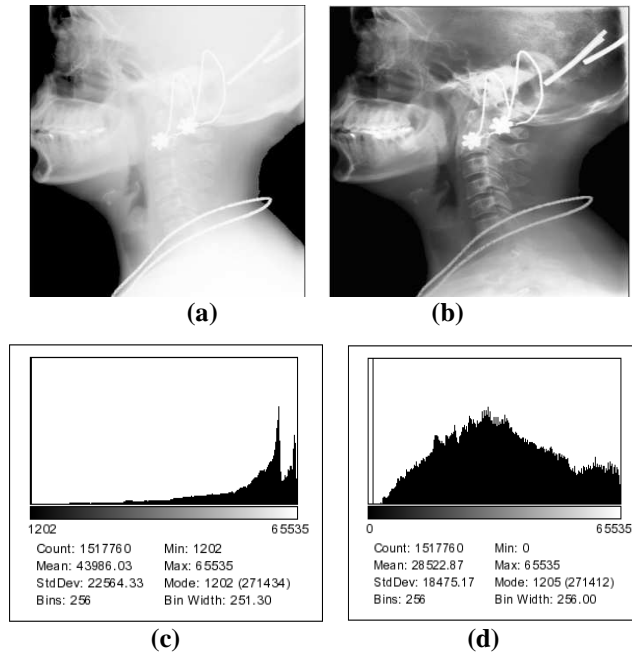
**Figure 2: The Complete Unsharp Filtering Operator**

Unsharp filtering is a more advantageous filter as fine details and edges are better enhanced through this technique.

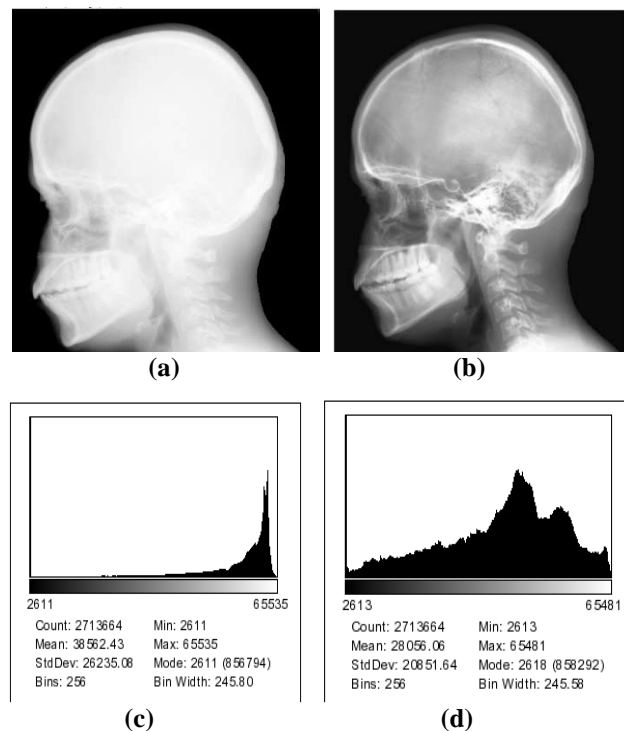
**RESULTS**

The proposed algorithm was applied on six sample images obtained from the SKAN-DR machine. The original images are in the raw2 format. This implies the original detector output image first undergoes pixel and gain correction. This is known as raw1 image. Then the raw1 format image undergoes anatomy related flip, rotate and auto-shuttering. Finally this image is called the raw2 image. The images are saved as just raw images and then worked with in MATLAB.

Some results are illustrated below as a comparison of the original image and outcome of the algorithm:



**Figure 3: (a) Original Image of a Female Cervical Spine; (b) Enhanced Image; (c) Histogram of Raw Image (a); (d) Histogram of Enhanced Image (b); The Images are of Size 1360x1116**



**Figure 4: (a) Original Image of a Male Head; (b) Enhanced Image; (c) Histogram of Raw Image (a); (d) Histogram of Enhanced Image (b); the Images are of Size 1774x1556**

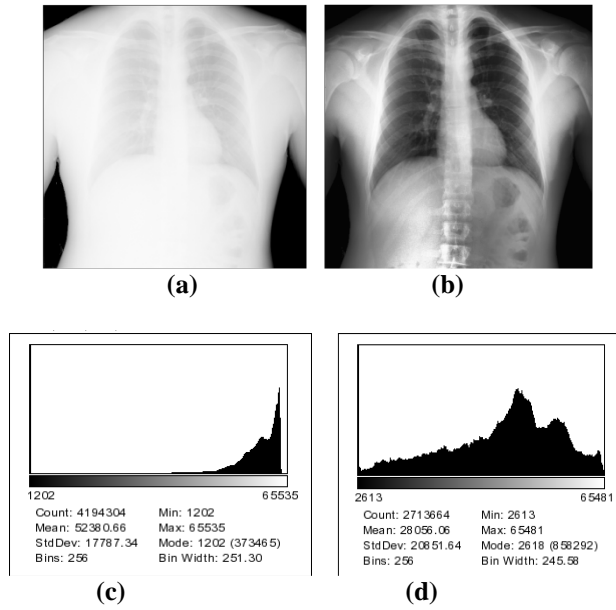


Figure 5: (a) Original Image of a Male Chest; (b) Enhanced Image ;(c) Histogram of Raw Image (a); (d) Histogram of Enhanced Image (b); the Images are of Size 2048x2048

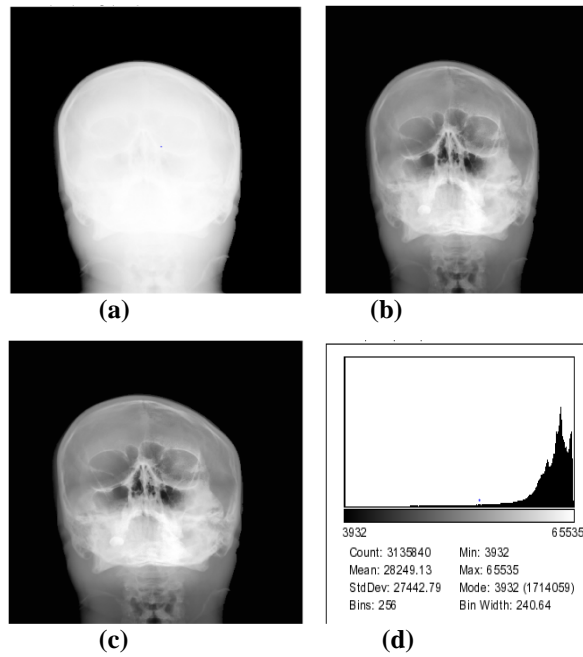


Figure 6: (a) Original Image of a Male Head (Posterior); (b) Enhanced Image; (c) Histogram of Raw Image (a); (d) Histogram of Enhanced Image (b); The Images are of Size 1880x1668



(a) (b)

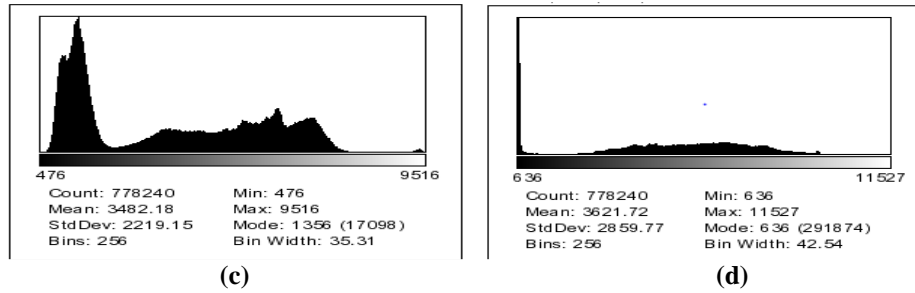


Figure 7: (a) Original Image of a Female Palm; (b) Enhanced Image; (c) Histogram of Raw Image (a); (d) Histogram of Enhanced Image (b); The Images are of Size 608x1280

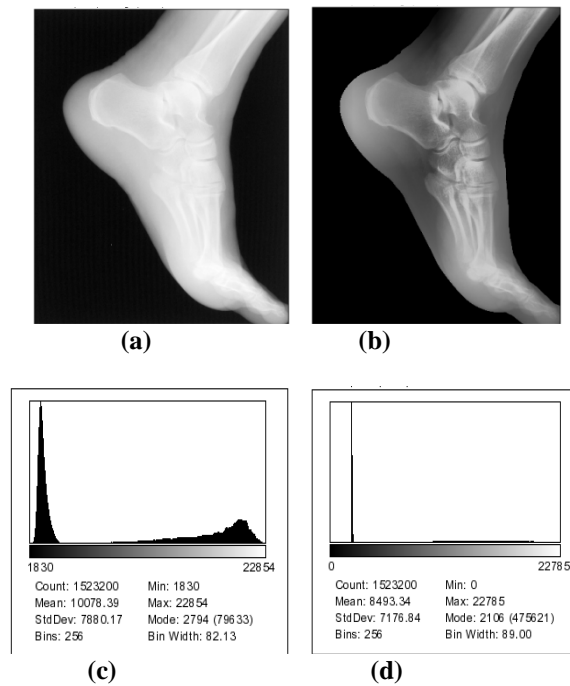


Figure 8: (a) Original Image of a Male Ankle; (b) Enhanced Image; (c) Histogram of Raw Image (a); (d) Histogram of Enhanced Image (b); The Images are of Size 1400x1088

**RESULTS EVALUATION**

The results were evaluated by clinical experts. Doctors are the best set of people to check if the proposed algorithm gives better result for right diagnosis compared with the original data. From the experts’ evaluation, it is obvious that the proposed algorithm improves the appearance of details significantly for all anatomy images that have been given as input to the algorithm. Enhancement with the proposed algorithm shows that the bone and soft tissue densities are clear and information can be extracted. The expert has presented that the enhancement of images can improve up to a very large extent from the original images and this result depends on medical image acquisition system. Also in every case the histogram has been analysed. The more spread out histogram is the requirement, implying that enhancement through equalization has been achieved.

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