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Survey on Contrast Enhancement Techniques for Medical X-Ray Images to Highlight The Abnormalities

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ABSTRACT
When medical X-rays are sent to certified radiologists for interpretation, accuracy of the results is strongly affected by poor contrast and high percentage of noise. It is thus necessary to develop suitable contrast enhancement techniques which not only highlights the Region of Interest but also removes the inherent noise from radiographs. Considerable research is cited in the literature to improve the visibility of abnormality in low contrast x-ray images. In this paper, a detailed literature survey on the various techniques used in spatial, frequency and spectral domains for contrast enhancement is presented.

Keywords-Medical radiographs, Histogram, Butterworth, Gaussian, Haar

I. INTRODUCTION

In general medical diagnostic techniques are indirect methods where the output images/signals should be analysed in order to identify the abnormality. Digital x-rays are widely used for breast cancer detection due to their reliability. The output x-ray images are sent to certified radiologists for interpretation. Radiologists should 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. However the major challenge in automated x-ray interpretation is due to poor contrast, artifacts and inherent noise in radiographs. Hence it is necessary to enhance the contrast of the radiographs before performing image segmentation to isolate the region of interest. Contrast enhancement is an image enhancement technique that refers to increasing the intensity difference between the Region of Interest and background. Though considerable research is done in such areas, as contrast enhancement is subjective in nature and is dependent on the nature of the original images, generalised contrast enhancement technique is not yet developed. In this paper, a detailed literature survey on the existing contrast enhancement techniques is provided.

II. REVIEW ON CONTRAST ENHANCEMENT TECHNIQUES IN SPATIAL DOMAIN

Mohammed et al (2013) proposed spatial enhancement and power law transformation for enhancing medical images. The proposed methodology involved the following steps. Initially the image sharpening was performed using Laplacian filter. This enhanced image was subtracted from the original image and Sobel filter was applied on the resultant image. Image smoothening was performed using an average filter. The Sobel filter and the average filter were logically ANDed. On the resultant image, Power law was performed. It was concluded that as the power law increases, the brightness of the image increases. However, further enhancement can be made using other enhancement techniques [1].

Sarage and Sagar Jambhorkar (2012) had proposed filtering techniques to enhance the contrast of x-ray images which were distorted due to noise and blurring. This technique involved the use of different filters such as median filter to remove noise and mean filter to remove the high frequency details. Performance of the proposed technique was measured in terms of Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR). Proposed technique was capable of not only removing noise but also in improving the quality of the X-ray image. Even though the filtering technique used here improves the quality of the image, this technique does not completely eliminate the noise in the X-ray images completely [2].

Tiwari and Yardi (2012) proposed an adaptive technique to improve the contrast quality of

dental X-Ray image using the Laplacian-of-a-Gaussian (LoG) filter. Adaptive contrast enhancement and de-enhancement with noise reduction for improving contrast quality of test Lena image using LoG filters was carried out using logic image statistics. They had considered the spatial domain for computation and determination of contrast transformation using adaptive neighbourhood windowing. This technique was also based upon the size of the object within the image. Local image statistics govern the transformation process to a larger extent. Here, the image enhancement technique was improved by replacing edge detection by LoG filters. They had proposed to replace the fixed power transformation function from converting original image into a mid-range intensity image. Hence, the LoG filter suited to be one of the best tunable/controllable edge detectors in context to adaptive contrast modification as compared to basic 3x3 edge detector [3].

Ritika (2012) has proposed a technique to enhance the contrast of the medical images using mathematical morphology with the help of multiscale structuring element. Initially, the image was given as an input over the structuring element. Black and white images and the sum of the white and the black image were found separately. However, there was a slight amplification of noise in this method. This algorithm could also be extended in future using non-flat structuring elements [4].

Ying Shen and Weihua Zhu (2013) had employed a machine based approach to tackle the challenge of eliminating the noise complexities of a medical image and to extract the required information in it. The machine based approach involved four stages of different algorithm to deal with the medical images. Initially, image smoothing was performed using Guassian, Mean and Gabor filters. Secondly, a mean filtering algorithm was implemented. It was based on the proposed approaches of Duba and Kart. Thirdly, the medical image enhancement was done to obtain the basic outline of the image. As the last step, a reduction algorithm was employed to obtain smooth and precise pictures. Detailed studies should be done to analyse the connection between the heart and other organs [5].

Mandip Kaur and Richa Sharma (2013) had proposed technique which restored the medical image using denoising technique for different types of noise. Gaussian noise, speckle noise, salt and pepper noise, rician noise and Brownian noise were the types of noise considered. There were two methods for image denoising namely spatial domain and transform domain. Linear filters destroyed the fine details. Bilateral filters worked effectively with high frequency areas but failed to work at low frequency areas. Bilateral filter didn't remove salt and pepper noise. Bilateral filters performed better than linear filters [6].

Umamaheshwari et al (2012) proposed a novel method to improve the quality of the image using Digital Imaging and Communication (DICOM) technique. Initially, low contrast DICOM image was given as an input. This image was stretched with the help of equalised contrast enhancement technique. The image obtained from this equalised contrast enhancement technique was made to undergo an anisotropic diffusion, which helped in the smoothening of the image. Finally, enhanced image was obtained. In the medical images, it resulted in poor quality and the noise in the images was not removed completely. As a result, these DICOM medical images were taken as test images for evaluation result [7].

Rathi et al (2010) proposed contrast enhancement and smoothening of medical images using histogram modification method. Initially, the original image was taken and then histogram equalisation was applied to enhance the image. This resultant image which was enhanced with histogram equalisation was made to pass through some filters for further enhancement. Hence, the final image that was obtained after the modification had higher contrast than the initial original image. It was concluded that the enhancement in the contrast of medical images can be done through Histogram Modification method [8].

Kalyan Chatterjee et al (2013) had implemented neuro-fuzzy inference system to obtain the clear image. Contrast enhancement was performed using Histogram equalisation that uses cumulative distribution function. Image enhancement using histogram equalisation was best suited for medical images [9].

Ritika and Sandeep Kaur (2013) had presented a mathematical morphology approach analysis. States of art techniques were compared with the approach of the authors' to solve the problem of low contrast images. The common methods used for contrast improvement in digital image were "Histogram equalization", "Contrast Limited Adaptive Histogram Equalization" (CLAHE). In CLAHE the local contrast of image was enhanced without noise amplification. This method was based on adaptive histogram equalization technique used for avoiding excess amplification originally developed for medical imaging. The white and black top-hat transformation was another method used for performing morphological contrast enhancement. It was concluded by saying that various image enhancement techniques had been mentioned. The multiscale morphology approach produced good results when compared to the results of the other state of art techniques [10].

Zohair Al-Ameen et al (2013) had compared seven famous techniques of improving the contrast of computed tomography of medical images. "Contrast Limited Adaptive Histogram Equalization (CLAHE) "because of its robustness and reliability process for CT image. CLAHE algorithm was tested for more than fifty CT images which had promising outcomes. The experimental results were divided into two phases. First phase was de-blurring of CT images before and after adjusting contrast, second phase concerns the denoising of CT images before and after adjusting the contrast. The pre-restoration contrast adjustment technique CLAHE had promising results. When this degraded CT images were restored using reliable method, Images restored without contrast adjustment had less visual details than the contrast adjusted one [11].

G.N. Sarage (2012) used a novel technique to enhance the contrast of X-rays with the help of low Pass and high Pass Filters. Initially, the X-ray image to be enhanced was taken. They had used a high boost filter to boost the performance of the image and the low pass filter was made to filter the noise in the image. This filtering method was one of the most significant methods for the contrast enhancement of medical X-rays. This technique was successful in achieving contrast enhancement. However, the image did not seem to be very clear although numerous filters had been used [12].

Siti Arpah Ahmed et al (2012) proposed an algorithm to analyse the image enhancement technique for dental X-ray image interpolation. Four enhancement techniques namely Adaptive Histogram Equalisation(AHE), contrast adaptive histogram equalization (CLAHE), median adaptive histogram equalization (MAHE) and sharp contrast adaptive histogram equalization (SCLAHE). Initially, they had collected ten dental X-rays. The Adaptive Histogram Equalisation involved the following steps. The original image was loaded first and it was separated into 3x3 masks (i.e.) it was splitted into 3x3 masks and the histogram (original image) was subjected to Adaptive Histogram Equalisation technique and finally, the splitted images were interpolated to obtain the enhanced dental X-ray image. Hence, it was found that the Adaptive Histogram Equalisation enhanced the image with better contrast which helped to improve the diagnostic ability in dental images [13].

Krishna Mohanta and Khanna (2013) had proposed an efficient contrast enhancement of medical X-rays called as the region growing approach, taking into account the shortcomings of the pre-built techniques. The region growing technique involved the implementation of some of the pre-built techniques and the concept of seed selection. In this technique, the seed point was selected to split the image into foreground and background region. The foreground region was enhanced by adaptive histogram equalisation. Then the background region was added to the foreground region. The resultant image was added with few parts of the original image to obtain the enhanced image. This enhanced image was further enhanced with the help of zooming and edge detection techniques. It was concluded that this enhanced image obtained through seed dependent region growing technique was found far clearer in contrast than all the pre-built techniques of contrast enhancement. This technique can be improved by implementation of multiple seed points and also a denoising technique can be added to improve the quality of the high noise images [14].

III. CONTRAST ENHANCEMENT TECHNIQUES IN FREQUENCY/SPECTRAL DOMAIN

Sabine Dippel et al (2012) had compared two types of multiscale methods and found out which one of the two gives better (or) clearer image. They have used the Laplacian pyramid and the fast wavelet transform. The original image was applied with the two multiscale methods. They compared the quality of the resultant of both the images and figured out the best one to use among the two multiscale methods. Finally, they found that the Fast Wavelet Transform method suffered from numerous drawbacks but the Laplacian Pyramid allows a smooth enhancement over a larger image. The visible artefacts were avoided in the Laplacian Pyramid and distortion like de-noising application or compression of images were done better by Fast Wavelet Transform than Laplacian pyramid [15].

Anamika Bharadwaj et al (2012) proposed a novel approach to medical image enhancement based on wavelet transform. Initially, the medical image was decomposed with the help of haar transform. Then the sub-images were decomposed using high frequency. The decomposed medical image and the sub-image were then added together. The noise present in the resultant image was reduced by the soft threshold method. Then the high frequency coefficients were enhanced by different weights. The enhanced image was filtered with the help of some filtering techniques. Hence, the enhanced image was obtained. It was concluded that the image obtained in this process seems to be very clearer which is very important in medical diagnostic purposes [16].

Samaraic and Majid Al Saiyd proposed a novel method for enhancing and sharpening medical colour digital images using wavelet transforms, and Sobel-Laplacian operators. First, the medical image was decomposed with wavelet transforms and then high-frequency sub images were decomposed with

Haar transform. Non-linear soft threshold filtering method was used to remove noise. The next method was the sharpening model in which input colour medical images was sharpened using RGB to HSV conversion, linear contrast stretch, edge detection using Sobel or Laplacian transforms. Hence, this method used two level wavelet transform due to which enhanced images were better than results with histogram equalization. Prototype enhancement procedure indicated that proceeding with Laplacian filtering technique provided more expedient results than that of the Sobel filtering technique [17].

Yusuf Abu Sa'dah et al (2010) proposed a novel hybrid method for enhancing digital X-ray radiograph images by seeking optimal spatial and frequency domain image enhancement combinations. The proposed methodology involved the following steps: First, the enhancement of image was done in the spatial domain method by applying cut-off frequency and power law parameters adjuster, negative transform, histogram equalisation and power law transform. Second, the transformed image was obtained in frequency domain using Discrete Cosine Transform. Third, image enhancement in frequency domain by using Gaussian LPF and HPF as well as Butterworth LPF and HPF were proposed. Fourth, an inverse transform image was taken into the spatial domain using inverse discrete cosine transform. At last, subjective test was applied to evaluate the enhancement method. Hence, the proposed work was intended to assist radiologists in diagnosing vascular pathology such as pulmonary embolism and from a medical point of view, the result gave radiologists added information about thoracic cage details including claricles, ribs and costochondra junction [18].

IV. SURVEY ON CONTRAST ENHANCEMENT BY MODIFYING THE SENSOR CHARACTERISTICS

Ritman (2006) enhanced the power of X-Ray imaging without the added radiation consequences. First method was to optimize the attenuation based imaging by use of monochromatic X-Ray instead of polychromatic (bremsstrahlung) X-rays which would limit the radiation exposure to useful X-Rays photon and also made the image contrast information more quantitative. K-edge absorption discontinuous subtraction imaging was used to selectively enhance contrast. Currently attenuation based X-Ray imaging methods cannot have resolution due to the undesirable X-Ray exposure consequences [19].

Kneip et al proposed a novel tabletop source of bright coherent synchrotron radiation to yield superior image quality and avoiding the need for scarce or expensive conventional source. The method was shown in the following steps. Wakefield acceleration and radiation generation in which a pulsed high power laser into a millimetre-sized plume of Helium gas which was immediately ionized and turned into a plasma due to which even low X-Ray intensity generates a superior image resolution. The second method was phase contrast imaging. In this X-Ray imaging, spatial contrast was a consequence of change in thickness and refractive index of the specimen. To benefit from phase contrast enhancement, sufficiently spherical i.e. sufficient transverse coherence was required [20].

George Zentai (2011) had proposed a technique to enhance the contrast of Mammogram using K-edge filtering technique. Women's breast consists of adipose and glandular tissue which consists of K-edge energy particles. Some part of the tissues might have higher concentration of these K-edge energies, and some have lower concentration. If the presence of K-edge energies at a portion was high, then the intensity of the radiation should also be high and if the K-edge energies were low, then the intensity can be low. It was concluded that this technique was used to obtain enhanced mammogram with the help of K-edge filters. However, the intensity of radiation was quite high which may be harmful to the human body [21].

Andrew Laine et al (2012) had proposed a technique to accomplish mammography enhancement through multiscale processing technique. This method used a linear combination of original images and two other smoothed images. The proposed technique enhanced the low contrast mammographs that were acquired with minimum dosage of x-rays. Hence, this technique can be used with older women. In spite of its advantage of lesser X-ray radiation, this technique cannot be used with younger women because of the over absorption of X-ray radiation through their fatty tissues in the body [22].

V. CONCLUSION

A detailed literature survey on the various contrast enhancement techniques are proposed in this paper. From the literature cited, these are the major conclusions.

- Spatial domain image enhancement technique namely Mean filter, Median filter and Laplacian of Gaussian filters are widely used for contrast enhancement in medical X-ray images.
- Haar transform based image enhancement technique provides better results than the spatial domain techniques.
- Proper contrast enhancement techniques can be used to provide high contrast x-ray images even with lesser dosage of x-rays.

- Frequency domain filters namely Butterworth and Gaussian filters are also used for enhancing x-ray images.
- Histogram based enhancement techniques namely AHE, CLAHE, SCLAHE also provide better enhancement than conventional spatial domain techniques.

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