Analysis of Histogram Based Compound Contrast Enhancement with noise reduction method for Endodontic therapy

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Abstract: Radiographs are essential to all phases of endodontic therapy. They inform the diagnosis and the various treatment phases and help evaluate the success or failure of treatment. Because root canal treatment relies on accurate radiographs, it is necessary to master radiographic techniques to achieve films of maximum diagnostic quality. Such mastery minimizes retaking of films and reduces the radiation exposed on patient due to which image quality is low contrast. Hence, image processing techniques are an acceptable technique that can be used to improve the quality of image to assist dentist for diagnosis. Digital dental radiograph images are often noisy, blur edges and low in contrast. We have proposed the combination of sharpening and enhancement method to overcome these problems. The impulse noise is reduced by using median filtering technique. Then filtered image is passed through the homomorphic filter to improve the image illumination. The processed dental images for root canal teeth are contrast enhanced by sharp contrast adaptive histogram equalization. The combination of median and homomorphic filter with SCLAHE is compound contrast enhancement method. The results are verified in terms of peak signal to noise ratio (PSNR) and entropy of image.

Keywords- Endodontic therapy; Radiographs; median filter; homomorphic filter; sharp contrast adaptive histogram equalization.

I. INTRODUCTION

Advancement in digital technology the first line of disease diagnosis via radiographs modalities relies mostly on x-ray images even though other modalities such as Magnetic resonance (MRI) and computer tomography (CT) provide more accurate interpretations [1]. This is also true for the field of dentistry where x-ray images are consistently used to assist endodontic therapy in deciding the appropriate treatment for root canal [2].Image processing method are helpful to visualized the radiograph in accurate manner .It also provide the facility to stored and transmits the radiograph for teledentistry application .In endodontic therapy bright clear improvement in diagnosis so contrast enhancement is one of the techniques that are actively being researched to improve the dental radiographs.

Approach that manipulates contrast is termed histogram equalization (HE) [3], [4]. This technique enhanced the original image through brightness intensity distribution applied to the whole image [5] which makes the image become over-enhanced and look unnatural [4]. Due to this effect, the use of contrast limited adaptive histogram equalization (CLAHE) is introduced in the image. CLAHE has produced encouraging results in enhancing the signal component of an image but in many cases it enhances noise too. However AHE, CLAHE techniques also enhances noise [6] and increases background in homogeneities [7] respectively. Therefore compound enchanchment method like sharp contrast adaptive histogram equalization with combination of median filterand Homomorphic filter overcomes the draw back of AHE & CLAHE. Compound SCLAHE consists of combination of image sharpening and contrast limited adaptive histogram equalization(CLAHE).

The main contribution of this work is to compare the diagnostic ability between original and enhanced images. While for the enhanced images, the focus of comparison is the quantitative measurement between the standard image enhancement techniques (HE, AHE, CLAHE) with the purposed algorithm Compound SCLAHE. A homomorphic filter is used to enhance image illumination and image sharpening is achieved by second derivative filter. Moreover, the scope of the proposed method is high as it improves the quality of Dental Radiograph image and hence will help in better and accurate diagnosis of root canal. The results are computed in the terms of PSNR and entropy of image. The goal of this research is to enhance dental radiographs by applying compound contrast enhancement method and to evaluate the

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dentists' visibility on detecting the abnormality on the dental radiography.

The rest of this paper is organized as follows. Section II briefly covers the methodology followed. Section III shows result and discussion and a short concluding remark is given in Section IV.

II. METHODOLOGY

A. *Compound Enhancement using Median filter and Homomorphic Filter*

Median filter is introduced as one of its pre-processing technique to reduce noise and identify its impact towards the contrast of the dental images. This technique updates the pixel value in ascending order. The centre pixel in the 3 x 3 area is then replaced with the median value
In medical image enhancement, noise reduction has great significance before performing higher level processing steps. In a noisy medical image, these noisy pixels are replaced by new pixel values which are introduced using median filter. The median filter is a non linear filter [9] with either 3x3 or 5x5 window size to achieve optimum smoothing and noise reduction.[10]

Enhancement in contrast after applying CLAHE, leads to low illumination and reflectance components in some important visual areas. Homomorphic filtering is important technique to enhance these components. To make the illumination of an image more even, the high-frequency components are increased and low-frequency components are decreased, because the high-frequency components are assumed to represent mostly the reflectance in the scene (the amount of light reflected off the object in the scene), whereas the low-frequency components are assumed to represent mostly the illumination in the scene. That is, high-pass filtering is used to suppress low frequencies and amplify high frequencies These components are described as *i(x,y)* and *r(x,y)* . Eq (4) Shows the mathematical model of homomorphic filter:

$$F(x, y) = i(x, y)r(x, y) \tag{4}$$

The intensity of *i(x,y)* changes slower than *r(x,y)* because of the fact that *i(x,y)* has more low frequency components than *r(x,y)*. For this reason first image is transformed into frequency domain, using some transformation function. Most common is Fourier transform. Various steps to perform homomorphic filtering is :

a) Input image to be processed
b) Take Log of the image
c) Apply Discrete Fourier transform
d) Apply High pass filter.
e) Apply Inverse Discrete Fourier Transform.
f) Take exponential function
g) Processed output image.

We have achieved sufficiently better image with a Gaussian High Pass filter used in Homomorphic filtering. This image is given as an inpuit to SCLAHE.

B. *Sharp Contrast Limited Adaptive Histogram Equalization based contrast enhancement*

The histogram of the image gives the occurrence of different gray levels in a form of graphical representation so that better description of the appearance of the image can be achieved. To improve the visual representation of the image, histogram equalization is used. Our method differs from ordinary histogram equalization [8] in the respect that the adaptive method computes several histograms, each corresponding to a distinct section of the image, and uses them to redistribute the lightness values of the image. It is therefore suitable for improving the local contrast of an image and bringing out more detail. For a 2-D image, Eq (1) shows the histogram of the input image:

$$H(n_k) = n_k \tag{1}$$

Where n_k is k[th] gray level and n_k is number of pixels having gray level n_k. The PDF of gray level is given by Eq (2):

$$P(n_k) = n_k \tag{2}$$

The pitfall of histogram equalization is that it does not provide any means to adjust enhancement level so the proposed method overcomes this drawback by controlling the level of contrast enhancement. This proposed technique is Contrast limited Adaptive Histogram Equalization. Since the contrast enhancement is made adaptive by introducing the parameter α. Hence, CLAHE differs from ordinary adaptive histogram equalization in its contrast limiting. However, because HE operates in global contrast of the image, the disadvantage is that it may increase the contrast of background noise and resulting in lower usable signal. Due to that AHE is introduced by multiple local window size area, emphasizes local contrast rather the overall contrast.

Though, AHE drawbacks were that its operation resultant wash out effect, introduces artifacts and losing out the image details. Consequently, the Contrast Limit Histogram Equalization (CLAHE) is created by limiting the local contrast-gain by restricting the height of local histogram

In the case of CLAHE, the contrast limiting procedure has to be applied for each neighborhood from which a transformation function is derived. CLAHE was developed to prevent the over amplification of noise that adaptive histogram equalization can give rise to. Still CLAHE problem is linked to high contrast in both foreground and background increasing the visibility of the main mass at the cost of simultaneously creating small yet misleading intensity in homogeneities in the background.

This is achieved by limiting the contrast enhancement of AHE. The contrast amplification in the vicinity of a given pixel value is given by the slope of the transformation function. This is proportional to the slope of the neighborhood cumulative distribution function (CDF) 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 neighborhood region.

Let H be the histogram of input image, H_1 is the uniform histogram of input image. Now we have to obtain the modified histogram H_2 such that it should be very closer to H so that proper optimization is achieved by limiting value of α between 0 to 1. By varying value of α from 0 to 1, we get the over enhancement as well as under enhancement.

$$H_2 = \alpha \mathrm{H} + (1-\alpha)\, \mathrm{H}_1 \qquad (3)$$

For a particular Dental Radiograph image the optimum value of by which we have achieved encouraging results is α = 0.1. Eq (3) shows the modified histogram using CLAHE of the input image.

SCLAHE consists of combination of image sharpening and contrast limited adaptive histogram equalization (CLAHE). The purpose of using the sharpening filters is to sharpen the outline of the dental image features. This work utilized Laplacian filter to perform image sharpening process.

Laplacian detects the outlines of the objects by convolving a mask with a matrix centered on a target pixel. The Laplacian detects the edge using a mask as in Fig. 1.

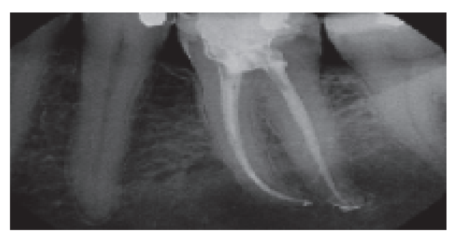
	-1	
-1	**4**	**-1**
	-1	

Fig.1 Laplacian Edge Detection mask

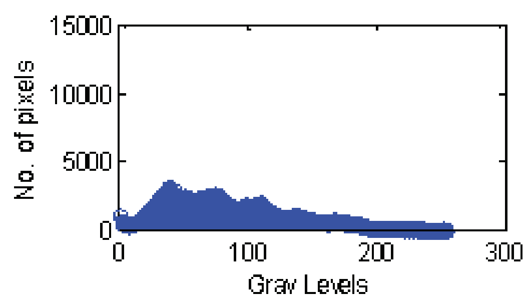
The Methodology can be summarized as follows: First the image is pre-processed using a 3x3 median filter. Since the dental radiographs are of low illumination, so it is passed through a homomorphic filter with Gaussian High pass filter. The resultant image is then subjected for contrast enhancement through various techniques like AHE, CLAHE and SCLAHE. Then to assess the image quality, we have calculated statistical parameters like PSNR and entropy.

III. RESULTS AND DISCUSSION

Experiments were performed on several Dental radiograph images of root canal. Initially in the pre-processing step the image is resized into 512 x 512. This methodology proposes a novel technique for noise reduction and better illumination of the root canal images. In the first step the original dental radiograph image of root canal and its respective histogram is generated. Fig. 2 shows the original image and its histogram.



(a)



(b)

Fig.2 (a) Root canal Dental Radiograph image
(b) Histogram of original image

The noise present in the image is also of concern so an initial pre-processing is done using Median filter So a noise reduction method has to be introduced. Hence the original image is passed through the median filter. The median filtered image is shown in Fig. 3

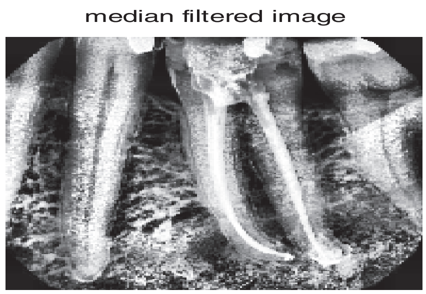


Fig. 3 Median Filtered Image

Now, to improve the illumination of the image homomorphic filtering is used. In this method, the Gaussian high pass filter with lower cut off frequency of 0.099 and higher cut off frequency of 1.01 is used. Fig. 4 shows the processed image with better illumination.

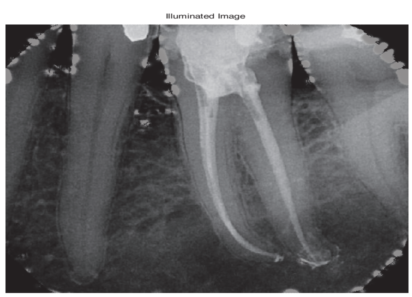


Fig. 4 Homomorphic filtered image

In the next step, histogram modification is done by using CLAHE technique. Here the level of enhancement is controlled by parameter α. By choosing the value of α=0.1 we got the best results. Fig. 4 shows the modified image by CLAHE.

Fig 5. Modified Dental Radiograph image by CLAHE

To achieve better image enhancement SCLAHE is used which consists of combination of image sharpening and contrast limited adaptive histogram equalization (CLAHE). Sharpening algorithm is used to sharpen the outline of the dental radiograph features as shown in Fig. 6.

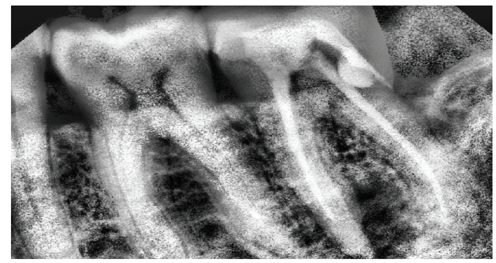


Fig 6. Sharpened Dental Radiograph image by SCLAHE

For image quality assessment two parameters PSNR and entropy of the image is chosen. The PSNR is explained by Eq. (5).

$$PSNR = 20 \log_{10}\left(\frac{Max\ pixel\ value}{\sqrt{Mean\ Square\ Error}}\right) \quad (5)$$

Table I shows the results of PSNR at each stage of the methodology with varying value of α.

Table I : PSNR at each stage with Varying value of α

α	HE	AHE	CLAHE	Compound SCLAHE
0.1	10.15	10.26	10.92	12.23
0.2	10.08	10.19	10.76	11.41
0.3	9.98	10.09	10.61	10.61
0.4	9.89	10.00	10.43	10.43
0.5	9.77	9.88	10.22	10.22
0.6	9.68	9.79	10.08	10.08
0.7	9.66	9.77	10.05	10.05
0.8	9.66	9.77	10.05	10.05
0.9	9.66	9.77	10.05	10.05
1.0	9.66	9.77	10.05	10.05

From table I it is found that at α=0.1 we got the highest value of PSNR. Entropy of an image represents the randomness present in the image. The entropy is explained by Eq. (6).

$$Entropy = -\sum P(x_i)\ \log_b P(x_i) \quad (6)$$

Where $P(x_i)$ is the probability mass function of image *i.* Table II shows the decrease in entropy after each stage of the algorithm followed with varying value of α.

Table II : Entropy at each stage with varying value of α

α	HE	AHE	CLAHE	Compound SCLAHE
0.1	5.9839	0.0024	7.8933	7.9043
0.2	5.9911	0.0190	7.9013	5.9623
0.3	5.9865	0.0169	7.9046	5.8305
0.4	5.9841	0.0188	7.8986	0.0072
0.5	5.9913	0.0179	7.8932	0.0072
0.6	5.9904	0.0178	7.9026	0.0072
0.7	5.8979	0.0166	7.9047	0.0072
0.8	5.8979	0.0166	7.9047	0.0072
0.9	5.8979	0.0166	7.9047	0.0072
1.0	5.8979	0.0166	7.9047	0.0072

Based on table I and table II, it is observed that the best results are found at α=0.1. The PSNR and entropy is 12.23 and 0.0072 respectively.

IV. CONCLUSION

In this paper, a novel approach is proposed to enhance Dental Radiograph images of root canal by amalgamating three techniques i.e median filtering homomorphic filtering with sharpening based contrast enhancement SCLAHE. Thereby, achieving high contrast enhancement with even illumination and noise reduction. This workshows that SCLAHE have the ability to enhance the subjectively image quality and providing better information for dentists. This work gives encouraging results with high PSNR of 12.23 and low entropy of 0.0072. The scope of this work can be extended to other medical images as well and different noise reduction techniques can be implemented to get better results.

REFERENCES

[1] Estrela C, Bueno MR, Leles CR, "Accuracy of cone beam computed tomography and panoramic and periapical radiography for detection of apical periodontitis." International *Endodontic Journal, Volume 3, Issue4,* 2008, page(s):273-279.

[2] Cotton TP, Geisler TM, Holden DT, " Endodontic applications of cone-beam volumetric tomography" International *Endodontic Journal* . ,2007, 33, page(s): 1121-1132.

[3] Patel S, Dawood A, Mannocci F, " Detection of periapical bone defects in human jaws using cone beam computed tomography and intraoral radiography" *International Endodontic Journal, Volume 42,*2009, page(s):507-515.

[4] Patel S., "New dimensions in endodontic imaging: Cone beam computed tomography" International *Endodontic Journal, Volume 42, Issue 6,* 2009, page(s): 463-475.

[5] W. C. Scarfe, A. G. Farman, and P. Sukovic. "Clinical Applications of Cone-Beam Computed Tomography in Dental Practice" Journal of the Canadian Dental Association, volume 72, Issue 1, 2006, page(s):75-80.

[6] W. De Vos, J. Casselman and G. R. J. Swennen, "Cone-Beam computerized tomography (CBCT) imaging of the oral and maxillofacial region A systematic review of the literature" International Journal of Oral Maxillofac, volume 38, 2009, page(s): 609-625.

[7] Yoon, H., Han, Y, & Hahn, H. " Image Contrast Enhancement based on Sub-histogram Equalization Techniques without Over-equalization Noise" *International Journal of Computer Science and Engineering* ,volume 3, Issue2, 2005, page(s): 121-126.

[8] R. Dale-Jones and T. Tjahjadi, "A study and modification of the local histogram equalization algorithm,"Pattern Recognit. vol. 26, no. 9, pp.1373–1381, 1993

[9] Stavropoulos A, Wenzel A., "Accuracy of cone beam dental CT, intraoral digital and conventional film radiography for the detection of periapical lesions. An ex vivo study in pig jaws" *Cliical Oral Investigation, Volume 11, Issue ,* 2007, page(s):101-106.

[10] N. C. Gallagher, Jr. and G. L. Wise, (1981). A Theoretical Analysis of the Properties of Median Filters.IEEE Transactions on Image and Signal Processing, Vol. 29, pp. 1136-1141

http://www.ee.columbia.edu/~dpwe/e4810/matscripts.html