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

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Abstract: Radiographic imaging is essential in diagnosis, treatment planning and follow-up in endodontic. The new 3D imaging technologies like cone-beam computed tomography (CBCT) that are available in dental practice shows great promise in this field as it makes possible the extraction of the dental root canal shape information.
CBCT reduces the radiation exposed on patient due this image quality is low contrast. Hence, image processing techniques are robust and acceptable technique that can be used to improve the quality of image to assist dentist for diagnosis. In the proposed paper, a study was carried out to enhance the dental images for root canal teeth by adaptive histogram equalization and impulse noise is reduced by using median filtering technique. Then filtered image is passed through the homomorphic filter to improve the image illumination. The results are verified in terms of peak signal to noise ratio (PSNR) and entropy of image.

Keywords- Endodontic therapy; CBCT imaging; median filter; homomorphic filter; adaptive histogram equalization.

I. INTRODUCTION

The practice of endodontic is currently in demand due to fast treatment in dental radiography. CBCT [1] has enabled the practitioner to examine endodontic anatomy and related diseases in an improved way [2]. As compare to CT in CBCT a rotating gantry is accomplished with an x-ray source and detector which are fixed. Due to rotating gantry it provide three dimensional view of radiograph [4]. The use of dental radiography technique like CBCT has increased the efficiency in diagnosis [1], [3].but one major issue in CBCT is that due to high density adjacent structures, such as enamel , radiopaque materials such as metal posts, restorations and root filling materials produces images scattering and beam hardening artifacts[5].

The movement of patient produces additional artifacts during the radiographic process. For health reasons CBCT is used instead of traditional scanning method in order to reduce the amount of radiation exposed on the patient. Due to low radiation, CBCT degrades the image perceptual quality [5], [6].In canal region mostly diagnosis images are low contrast and containing noise. So robust adaptive contrast enhancement and noise reduction algorithm are needed to improve the CBCT image for endodontic therapy.

In dental radiographs contrast of images can be improve with the help of image enhancement techniques. Approach that manipulates contrast is termed histogram equalization (HE) [7], [8]. In histogram equalization method brightness intensity distribution applied to the radiograph image [7] due to this image become over-enhanced and looks unnatural [8]. So that the use of contrast limited adaptive histogram equalization (CLAHE) is introduced in image. CLAHE has produced encouraging results in enhancing the signal component of an image but in many cases it enhances noise too. Noise enhancement introduces the artifacts in the output image and theses artifact reduces the ability of observer to detect information contained in the image.

The main contribution of this work is to implement CLAHE on CBCT [5], [6] images followed by median filter. A homomorphic filter is used to enhance image illumination and image sharpening. Moreover, the scope of the proposed method is high as it improves the quality of CBCT image and hence will help in better and accurate diagnosis of root canal. CBCT overcomes the drawback of CT [9] scan and is not harmful for the human being. For image quality assessment two parameters PSNR and entropy of the image is chosen.

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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. 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. Since adaptive method computes several histograms where each corresponds to a distinct section of the image. It is therefore more advantageous to improve the local contrast of an image. For a 2-D image, Eq (1) shows the histogram of the input image:

$$H(n_k) = n_k \qquad (1)$$

Where n_k i 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):

$$P(n_k) = n_k \qquad (2)$$

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. 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.

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) i.e. value of the histogram at that pixel value. Before computing the CDF, CLAHE clips the contrast level of the distributed histogram. It thus limits the slope of the CDF and transformation function. The value at which the histogram is clipped depends on the normalization of the histogram and 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.

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

Eq (3) shows the mathematical formulation for modified histogram using CLAHE of the input image. The optimum value of α may vary from image to image i.e. quality and type of image viz. CT, X-Ray, MRI etc.

B. Median filtering with Homomorphic filtering

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 [10]. The median filter is a non linear filter with either 3x3 or 5x5 window size to achieve optimum smoothing and noise reduction.

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 of the image are increased and low-frequency components are decreased. The high frequency components show the amount of reflectance and low shows the illumination content. 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:

$$F(x, y) = i(x, y) r(x, y) \qquad (4)$$

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.

After obtaining homomorphic filtered image, we have calculated some metric values to validate our method.
For image quality assessment two parameters PSNR and entropy of the image is chosen. The PSNR is explained by Eq. (5).

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

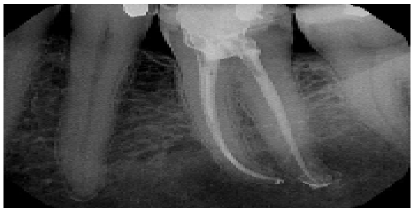
Entropy of an image represents the randomness present in the image. The entropy is explained by Eq. (6).

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

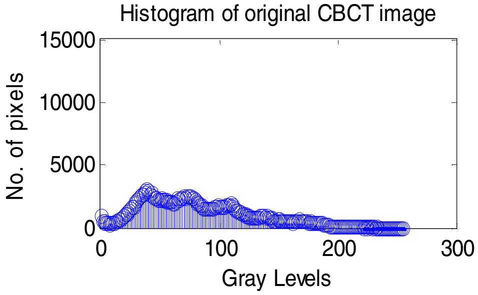
III. RESULTS AND DISCUSSION

Experiments were performed on several CBCT 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 CBCT images. In the first step the original CBCT image of root canal and its respective histogram is generated. Fig. 1 shows the original CBCT image and its histogram.

CBCT image of Root canal



(a)



(b)

Fig.1 (a) Root canal CBCT image
(b) Histogram of CBCT 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. 2 shows the modified image by CLAHE.

CLAHE image

Fig 2. Modified CBCT image by CLAHE

With the enhancement of the image, the noise present in the image also gets more prominent. So a noise reduction method has to be introduced. The CLAHE image is corrupted by salt and pepper noise. Hence the processed image is passed through the median filter. The median filtered image is shown in Fig. 3

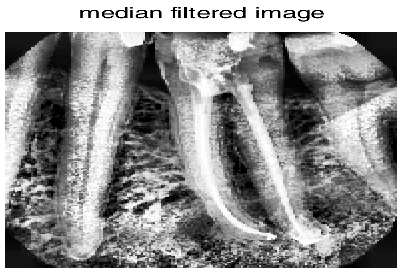


Fig. 3 Median Filtered Image

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. The illumination of processed image is enhanced with homomorphic filter as shown in fig 4.

Fig. 4 Homomorphic filtered image

The comparison of all contrast enhancement methods is formulated below.

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	CLAHE	HE	Median Filtered Image	HM-Filter Image
0.1	10.92	10.15	10.26	96.32
0.2	10.76	10.08	10.19	51.00
0.3	10.61	9.98	10.09	53.80
0.4	10.43	9.89	10.00	51.30
0.5	10.22	9.77	9.88	51.55
0.6	10.08	9.68	9.79	51.19
0.7	10.05	9.66	9.77	51.93
0.8	10.05	9.66	9.77	51.93
0.9	10.05	9.66	9.77	51.93
1.0	10.05	9.66	9.77	51.93

From table I it is found that at α=0.1 we got the highest value of PSNR.

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	CLAHE	HE	Median Filtered Image	HM-Filter Image
0.1	7.8933	5.9839	5.9800	0.0024
0.2	7.9013	5.9911	5.9874	0.0190
0.3	7.9046	5.9865	5.9833	0.0169
0.4	7.8986	5.9841	5.9814	0.0188
0.5	7.8932	5.9913	5.9888	0.0179
0.6	7.9026	5.9904	5.9861	0.0178
0.7	7.9047	5.8979	5.9842	0.0166
0.8	7.9047	5.8979	5.9842	0.0166
0.9	7.9047	5.8979	5.9842	0.0166
1.0	7.9047	5.8979	5.9842	0.0166

Based on table I and table II, it is observed that the best results are found at α=0.1. The PSNR and entropy at α = 0.1 is 96.32 and 0.0024 respectively.

IV. CONCLUSION

In this paper, a novel approach is proposed to enhance CBCT images of root canal by amalgamating three techniques i.e CLAHE, median filtering and homomorphic filtering. Thereby, achieving high contrast enhancement with even illumination and noise reduction. This work gives encouraging results with high PSNR of 96.32 and low entropy of 0.0024. 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.

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