Volume 9, Issue 6
December 2020

ITEE Journal
Information Technology & Electrical Engineering

ISSN: - 2306-708X

Conventional Dental Interaoral Periapical (IOPA) image quality improvement using Denoising Convolution Neural Network (DnCNN)

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ABSTRACT

Digital image processing is playing a very important and key role in medical domain. There are numerous applications where digital imaging is required. One of the main research area of digital imaging is dentistry. Many researchers and scientist find daily new challenges and critical diseases to diagnose properly by different imaging techniques. In dentistry mostly x-ray films are used to diagnose and detect tooth disease. As technologies are changing and updating day by day, in dentistry also diagnosis method updating from conventional imaging to digital one. Recently, in dentistry different digital imaging techniques are used like, 2D, 3D digital radiography. Though dentist is going towards computer based system, 3D cone beam computed tomography but most of dentist are preferring conventional practice. We are focusing on conventional method which is again preferable by dentist in remote areas and villages. In this paper we are focusing the quality improvement of conventional dental film based radiographs by removing noise and haze. The proposed quality enhancement work consists of two stages, one removing haze from dental intraoral periapical radiographic image and second removing noise by denoising convolution neural network (DnCNN). The performance metrics Peak Signal-to-Noise Ratio (PSNR), Signal-to-Noise Ratio (SNR) and Mean Square Error (MSE) are calculated and observed. The minimum and maximum values of PSNR in dB calculated 29.2362and 39.4322 respectively.

Keywords— *Image processing, Medical imaging, Dentistry, radiographs, MRI, CBCT, Haze, Denoising Convolution Neural Network*

1. INTRODUCTION

Medical imaging is having very much important since the evolution and use of x-rays. There are number of applications where imaging playing a key role now a days. As utmost application of imaging technique is in dentistry. Dentistry is itself a broad domain where dentists are more comfortable with x-rays. Wilhelm Konrad Roentgen discovered x-rays in 8th November 1895 [1]. Dental radiography is the art and science of making picture of teeth with the x-rays [2] it was started with Dr. Otto Walkhoff in Braunschweig who made the first picture of the teeth [3] with 25 minutes of exposure time. In dentistry, dentists are more preferring tooth x-rays to diagnose and detect different diseases. Two-dimensional (2D) imaging modalities have been used in dentistry since the first intra-oral radiograph was taken in 1896 [4]. Now we are using 3D imaging technique which is better and providing quality oriented images. As before 3D there is an era of conventional imaging technique, 3D imaging is came in picture again dentists prefer conventional methods. It is more comfortable and economically for patients. An image can be adjusted and a clearer picture can be produced in order to identify areas of concern. Image denoising is a process to remove unwanted noise present over an image, which cause degradation of quality of image. There are various methods to remove nose and restore image but now a days convolutional neural network (CNN) is giving better results compared to other traditional model-based methods [5]. Recently, CNN-based methods have been developed rapidly and have performed well in many low-level computer vision tasks [6]. Medical research has no option instead of CNN, as it is achieving expert-level performances in various fields [7]. Another parameter is to remove haze from an image which is a traditional task. The presence of haze often disturbs the visual effects of image which cause the poor quality effect in image, hence the quality of an image greatly affects the performance of computer vision applications [8].

2. LITERATURE SURVEY

Dental radiographs are playing major role since the use of x-rays in clinical diagnosis. There are different techniques used clinically as per requirement like conventional film based, 2D digital, RVG (Radio-Visio-Graphy), and recently 3D CBCT (Cone beam computed tomography) is in consideration for diagnosis. The key advantage of preference of CBCT technology is a lower effective radiation dose than traditional CT scans [9]. There are number of applications of which associated with detection of tooth caries. As far as concerned with conventional dental film based radiographs, the IOPA (Intraoral Periapical) covers up to four teeth upper or lower and OPG (Orthopantomogram) covers whole upper and lower teeth full mouth scan figure 1(b) shows OPG radiograph.

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In this paper we are focusing on only IOPA radiographs for experimentation and analysis.

A. IOPA and OPG film

At the starting of use of x-rays in dentistry conventional film based method is used. This is also an effective method generally used for detection of apical infection. The x-ray film gives the view of entire crown and root of the teeth and surrounding alveolar bone which provides vital information to aid in the diagnosis of the most common dental diseases [10].

(a) (b)

Fig. 1: a) Intraoral Periapical radiograph showing lower jaw four tooth, b) Orthopantomogram showing full mouth upper and lower jaw tooth.

Different sizes of IOPA films are available with respective the patient and diagnosis required. Figure shows various dimensions of films used clinically for child, adult and adult (post) respectively.

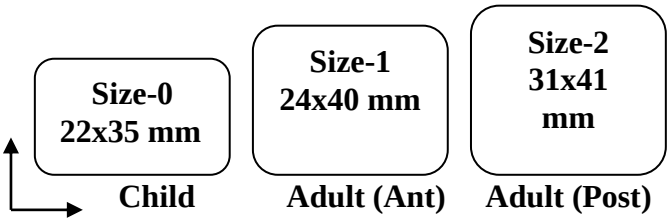


Fig. 2: Dimensions of IOPA films as according to patient

In conventional method x-rays are shooted through a sensor on film for a fraction of time and then film is developed in dark room in chemical solutions. Conventionally as once film is developed no further changes or editing is possible, hence next era is digital imaging technique. Digital imaging provides better hands on image enhancement and better quality of results. Digital image processed by appropriate software to analyse by different angles for diagnosis.

B. Haze in captured images

Haze can be defined as a slight confusion or something unclear. It reduces the visibility in image. Hazy image means something that is clouded over or covered by mist or haze, or something that is unclear, vague or not well-defined [11]. As according to Huzaifa Rashid et.al., Haze is a natural phenomenon in which the dust, smoke and other particles alter the vision of the sky to reduce the visibility. The visibility from the camera is faded due to the interference with the environmental light source reflected by the dust particles. The blurred image gain noise and loses the color attenuation [12]. The captured images are poor quality and having aging issues. After a long time dental IOPA films information getting disappear and film somewhat is unreadable. Degradation of film causes low contrast and makes the object features difficult to identify by human vision and by some outdoor computer vision systems. Authors suggested that image dehazing is an important issue and has been widely researched in the field of computer vision [13]. Another artifact related to poor quality image is fogging which is softening and obscuring of the image that cause in increased density and decrease in film contrast [14].
Xuemei Wang et.al. described the formation of a hazy image as follows equation (1).

$$I(x,y)=L\infty\cdot\rho(x,y)\cdot e-\beta\cdot d(x,y)+L\infty\cdot(1-e-\beta\cdot d(x,y))\ldots\ldots\ldots\ldots(1)$$

where I is the observed image, ρ is scene reflectance, L∞ is the global atmospheric light, β denotes the medium transmission coefficient, and d refers to the scene depth. For the sake of simplicity, L∞ and β are usually regarded as constant when dealing with haze removal [15].

C. Denoise CNN:

Unwanted information called noise in image. It is caused due to various sources and many external causes in transmission system and environmental factors which includes noise like Gaussian, Poisson, Blurred , Speckle and salt-and-pepper noise [16]. In medical imaging additive Gaussian noise (AWGN) is affecting more on image quality. The effectiveness of reading radiographs decreases causes non proper diagnose and patient have to go for retake and re exposure of x-rays. It is being tried to avoid retakes and radiation exposure on patient as radiation exposure is harmful to a certain extent. Convolution neural network (CNN) is very effective and useful technique in image processing to reduce the noise.

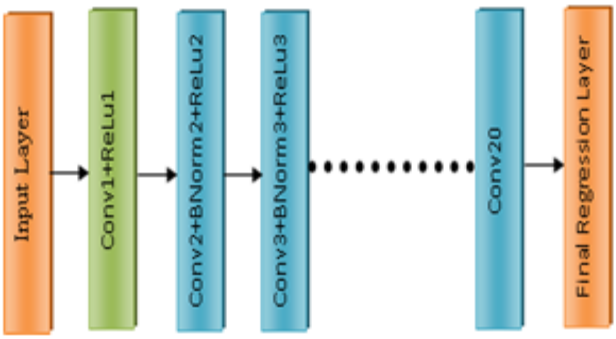


Fig. 3: Architecture of DnCNN network model

3. MATIAERLS AND METHODS

Proposed system is developed to enhance the quality of dental radiographs. The process of enhancement divides in two stages. Stage–I comprises preprocessing and

enhancement by reducing haze. The output of stage-I is Idho which is haze free output.

- Dataset preparation

The dental IOPA radiograph data are collected from various dental clinics. IOPA films collected which are recent to last five year saved x-rays. These films collected in hard copy radiographs. These hard films are captured by a camera and stored in a hard drive.

- Proposed system

The model for image enhancement is divided in two parts, the first part includes preprocessing on input data and then removal of haze. Figure shows stage-I block diagram of dental radiographs enhancement process, which comprises pre-processing and then haze remove. Input image is of variable size, it is resize to 256*256 size. This image is complimented and then reduces the haze. The output of stage-I, Idho is given input to next stage.

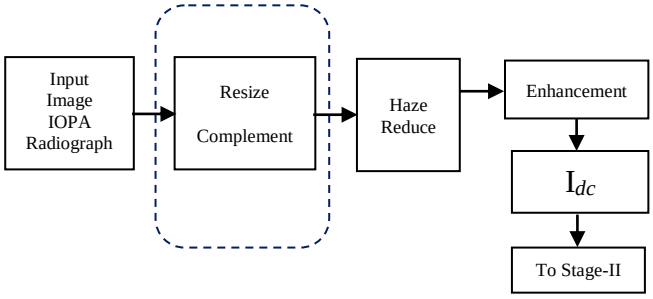


Fig. 4: Block diagram of preprocessing and haze removal.

Figure shows stage-ii block diagram for denoising process by convolution neural network. There are 59*1 layers, Denoising Convolutional Neural Network layers returns the layers of the denoising convolutional neural network (DnCNN) for grayscale images. Following are the properties of network layer which used for denoising. A median filter is applied on image to sharpen and improve the quality. Four parameters, PSNR (peak-signal to noise ratio), SNR (signal to noise ratio), MSE (Mean Square Error) and SSIM (structural similarity index) are used to check the quality and improvement in results.

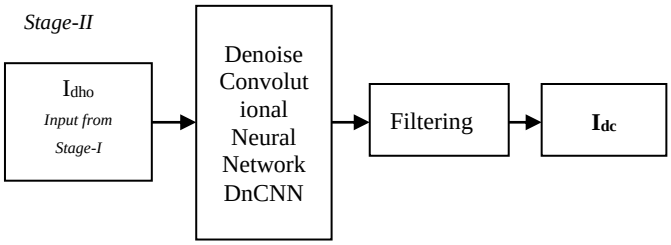


Fig. 5: Block diagram for DnCNN and filtering

net = Series Network with properties:
Layers: [59×1 nnet.cnn.layer.Layer]
InputNames: {'InputLayer'}
OutputNames: {'FinalRegressionLayer'}
layers = 1x59 Layer array with layers:

- Image quality parameters

a) PSNR computes the peak signal-to-noise ratio, in decibels, between two images.

$$PSNR = 10\log_{10}\left(\frac{R^2}{MSE}\right) \quad \text{..... (2)}$$

PSNR is a metric use to measure the quality of any image reconstructed/restored or corrupted image with respect to its reference or ground truth image. It is a full reference image quality measure defined as the maximum value of maximum signal power with respect to Mean square error assumed as noise power.

b) SNR:- As signal-to-noise ratio (SNR) is a key element which is used commonly in clinical observations also it is a baseline to develop medical image quality assessment algorithms17.

c) MSE:- Mean Square Error can be calculated as the square difference between reference image and reconstructed/restored image. Thus a higher value of PSNR indicates that the image is of higher quality and vice-versa. A 20 dB or higher PSNR indicates that the image is of good quality.
Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE) are used to comparing the squared error between the original image and the reconstructed image. There is an inverse relationship between PSNR and MSE. So a higher PSNR value indicates the higher quality of the image.

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(x(i,j) - y(i,j))^2 \text{.....(3)}$$

d) SSIM:- SSIM (structural similarity index) evaluates the structure of the image. The SSIM of a reconstructed image to ground-truth image is always 1, and with a value close to 1, one can tell the image is of good quality.

4. EXPERIMENTAL ANALYSIS

Performance analysis is done on 49 different dental radiographs. These all are IOPA radiographs collected from different clinics. The data base created of dental caries. Data set created of combination of clear, blurr, noisy and effected by aging factors. Overall data set is of degraded images which are difficult to read and analyzed by dentist. Table 1 show results obtained after preprocessing and enhancement after denoising convolution neural network. The highest PSNR value is obtained 39.4322 dB and lowest 29.2362 dB.

Table 1: PSNR, SNR and MSE values of resulted images

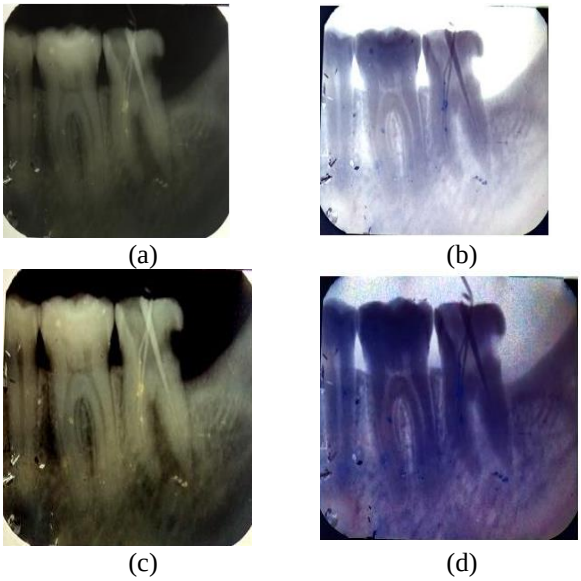
Image	PSNR	SNR	MSE
C1	32.3888	30.0461	37.515
C2	33.9128	30.9961	26.4122
C3	33.436	28.1536	29.4771

C4	30.4971	25.0741	57.9929
C5	35.8513	34.0549	16.9025
C6	31.5314	24.6437	45.7028
C7	31.8417	24.7951	42.5508
C8	31.8483	28.3326	42.4861
C9	33.7042	31.021	27.7118
C11	35.3964	32.0465	18.7691
C12	30.2826	26.503	60.9279
C13	29.7135	26.1193	69.4592
C14	35.4567	32.6647	18.51
C15	32.4665	30.1252	36.8497
C16	37.613	35.6544	11.2662
C17	36.1044	33.3047	15.9457
C18	33.1495	30.4659	31.4867
C19	35.6173	33.3983	17.8383
C20	37.0707	34.0948	12.7648
Iop1	37.8304	35.7516	10.7161
Iop2	31.0089	27.916	51.545
Iop3	39.4322	37.0298	7.4108
Iop4	33.9881	31.1765	25.9581
Iop5	32.4567	28.0749	36.9324
Iop10	31.9983	29.0779	41.0438
Iop11	34.259	32.3299	24.3881
Iop12	37.2446	32.9151	12.2635

Table 2: Average values of PSNR, MSE and SNR calculated for 49 images

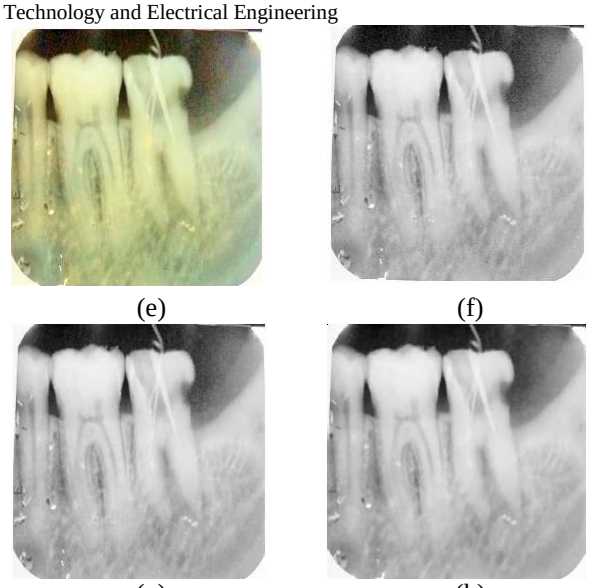
Parameters	PSNR	SNR	MSE
Average	33.3195	29.4397	34.8388
Min	29.2362	21.4681	7.4108
Max	39.4322	37.0298	77.5277

From experimentation results and analysis it is been noted that proposed system output images of dental IOPA radiographs showing improvement in quality of degraded, hazy and noisy image.



(a) (b)

(c) (d)



(e) (f)

(g) (h)

Figure 6: a) Input image of 256*256 size, b) Complement of input image, c) Reduced haze, d) Compliment of enhanced image, e) Output with reduce haze and enhancement, f) Gray scale converted image, g) Denoising by Convolution Neural Network, h) Filtered output

For figure 6, the Peak-SNR value is 31.5314 dB, SNR value is 24.6437 dB and calculated mean-squared error is 45.7028

5. CONCLUSION

In this paper, combination of a haze removal and a deep convolutional neural network (CNN) is proposed to improve the quality of dental IOPA radiograps by two methods as to dehaze and denoising image, where convolution is adopted to reduce network parameters and improve quality of image. Four point evaluations is done which shows the average PSNR value obtained 33.3195 dB and average MSE 34.8388. Local structural similarity index is about 0.7994.

REFERENCES

[1] Rade R Barbic, “120 Years Science the discovery of X-rays”, Pubmed, Med Pregl. Sep. (2016)

[2] Howard Riley Raper, “Elementary and Dental radiography”, Claudius Ash Sons and Co. Ltd. London, (1918).

[3] Dhaliwal Ambika, Singh Narender, Kapila Rishabh, Rajput Rajan, History of X-Rays in Dentistry, Annals of Dental Research, Vol 2 (1): (2012), 21-25

[4] Dr Mohammed A. Alshehri, Dr Hadi M. Alamri & Dr Mazen A. Alshalhoob, CBCT applications in dental practice: A literature review, DENTALTRIBUNE Middle East & Africa Edition, Media CME, pp.-8

[5] Wangmeng Zuo, Kai Zhang, lei zhang, Convolutional Neural Networks for Image Denoising and Restoration, Advances in Computer Vision and Pattern Recognition book series (ACVPR), Denoising of Photographic Images and Video, (2018), pp 93-123.

[6] Linwei Fan, Fan Zhang, Hui Fan and Caiming Zhang, Brief review of image denoising techniques, Visual Computing for Industry, Biomedicine, and Art, (2019), pp.1-12, https://doi.org/10.1186/s42492-019-0016-7

[7] Rikiya Yamashita, & Mizuho Nishio & Richard Kinh Gian Do & Kaori Togashi, Convolutional neural networks: an overview and application in radiology, Insights Imaging, (2018), pp.611–629, https://doi.org/10.1007/s13244-018-0639-9

[8] Tianlun Zhang, Xi Yang, Xizhao Wang, Ran Wang, Deep Joint Neural Model for Single Image Haze Removal and Color Correction, Journal of Information Sciences, Elsevier, (2020)

[9] Francesc Abella, Kala Morales, Iva´n Garrido, Javier Pascual,Fernando Duran-Sindreu, Miguel Roig, Endodontic applications of cone beam computed tomography: case series and literature review, Giornale Italiano di Endodonzia, (2015), pp. 38-50.

[10] A Gupta, PDevi, R Srivastava, B Jyoti, Intra oral periapical radiography - basics yet intrigue: A review, Review article, Bangladesh Journal of Dental Research & Education, Vol. 04, No. 02, (July 2014).

[11] https://www.yourdictionary.com/

[12] Huzaifa Rashid , Nauman Zafar, M Javed Iqbal , Hassan Dawood , Hussain Dawood, Single Image Dehazing using CNN, 2018 International Conference on Identification, Information and Knowledge in the Internet of Things, IIKI 2018,Science direct, Published by Elsevier B.V, Procedia Computer Science 147 (2019), pp. 124–130

[13] Wencheng Wang, Xiaohui Yuan, Recent advances in image dehazing, IEEE/CAA Journal of Automatica Sinica, Vol. 4, NO. 3, JULY (2017).

[14] Allan G. Farman, Dental Radiographic Pitfalls and Errors, American Dental Assistants Association Continuing Education Course, (2007)

[15] Xuemei Wang, Mingye Ju, Dengyin Zhang, Automatic hazy image enhancement via haze distribution estimation, SAGE Journal, Vol. 10 issue: 4, (April 18, 2018)

[16] NalinKumar, Mrs. M Nachamai, Noise Removal and Filtering Techniques used in Medical images, Oriental Journal of Computer Science & Technology, ISSN: 0974-6471, Vol. 10, No. (1), Mar (2017), Pp. 103-113

[17] Zhicheng Zhang, Guangzhe Dai, Xiaokun Liang, Shaode Yu,Leida li, Yaoqin Xie, Can Signal-to-Noise Ratio Perform as a Baseline Indicator for Medical Image Quality Assessment, IEEE Access, Vol. 6, (2018), pp.11534-11543

[18] Shuai Fang , Jingrong Yang, Jiqing Zhan, Hongwu Yuan, Ruizhong Rao, Image quality assessment on image haze removal, IEEE International Chinese Control and Decision Conference (CCDC), 23-25 May (2011).

[19] Zhang, K., W. Zuo, Y. Chen, D. Meng, and L. Zhang, Beyond a Gaussian Denoiser: Residual Learning of Deep CNN for Image Denoising, IEEE Transactions on Image Processing, Vol. 26, Number 7, Feb.(2017), pp. 3142-3155.

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