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OPG Images Preprocessing Enhancement for Diagnosis Purposes

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Abstract: ***Orthopantomogram (OPG) image is considered one of the techniques which plays a vital role in the dental diagnosis of diseases and its treatment. Generally speaking, the panoramic OPG images acquired with Orthopantomogram are corrupted by noise and have a poor visualization. For this reason, appropriate techniques for suppressing the noise and contrast improvement are required for the development. The current paper proposed an algorithm which include two-phases; noise reduction and contrast enhancement for OPG images. For noise reduction, adaptive median filter and discrete wavelet transform have been used for handling mixed noises which contains Salt and Pepper noise, Gaussian noise, and Speckle noise. In other words, this phase is capable of suppressing the noise even though preserving the important feature in the images. Subsequently, the contrast of OPG is enhanced by using morphology processing and contrast limited histogram equalization (CLAHE). Furthermore, the performance of noise reduction and contrast enhancement are evaluated separately with visual results and quantitative measurement. Moreover, noise reduction is in comparison averaged PSNR of 31.78 dB and averaged SSIM of 0.9115 for mixed noise in comparison with other filtrations techniques while the contrast enhancement phase is achieved an average AMBE of 27.356 and an average EME of 51.631 Module.***

Keywords: Orthopantomogram, OPG, Morphology, CLAHE, AHE

1. Introduction

There is no doubt that one of the major issues related to the medical images is that most of them are suffered from noise and other different quality-related problems and difficulties in extracting suitable information. Therefore, it necessary to design some techniques that can enhance the image in such a way so that, it will be suitable for further processing.

Having said that the nature of intra-oral digital radiographs has a low image quality due to low dose utilization. Then again, the strategy of low dosage utilization is related to its impact on patient's health. In this way image processing techniques such as image enhancements methods are the accepted methods to improve the radiograph's image quality. What's more, improvement of the quality of images has always considered one of the major tasks of medical image processing. In modern terms, improvements in sensitivity, resolution and noise reduction have equated higher quality with more prominent informational throughput [1]– [4].

Another key thing to remember is that there are numerous distinctive cases of distortions. One of the most predominant one is the distortion due to adding substance white Gaussian noise which can be caused by destitute image acquisition or by transferring the image information in noisy communication channels.

Additional, other types of noises incorporate impulse and speckle noises. Besides, noise can be presented by transmission errors and compression. In this way, denoising is often a necessary and the first step to be taken before the image information is analyzed. It is essential to apply a proficient denoising technique to compensate for such data corruption. Significantly, image denoising still remains a challenge for researchers since noise removal presents artifacts and causes blurring of the images [5].

In order to mitigate some of the problems recognized above, S. Arivazhagan et al; analyzed the performance of an Image denoising system for speckle noise by using Discrete Wavelet Transform (DWT) for four levels of DWT decomposition [5]. While Tarek A. Mahmoud and Stephen Marshall; utilize edge detected guided morphological filter for enhancing low contrasted medical images. Notably, this strategy gets to be fulfilled by suitably identifying the positions of the edges through threshold decomposition [3]. Siti Arpah Ahmed and et al. proposed a comparative and analytical study of using four image enhancement techniques for dental X-ray image interpolation. The objective of this work was to compare the diagnostic ability of original and enhanced images. Consequently, the results show that CLAHE and SCLAHE have been gotten the best result as a contrast enhancement [6]. Moreover, Veska M. Georgieva, and et al. Proposed an effective approach for dental X-ray image enhancement for detection of caries. (CLAHE) and morphological processing for contrast enhancement, then homomorphic wavelet filter is used to remove noise components and to eliminate non-uniformity luminance distribution [7]. Finally, Erwin; assessed the image quality improvements by utilizing three different techniques of image enhancement. So that, contrast enhancement, sharpening, and noise reduction are used. Likewise, the test results illustrate that the Image Sharpening has good results for this topic since it doesn't change information or pixel; it is close to the original image information [8].

This paper proposes a powerful hybrid filtration scheme which combines adaptive median filter and discrete wavelet transform as noise reduction tools; and a combination of morphology image processing and Contrast Limited Adaptive Histogram Equalization (CLAHE) for contrast enhancement to obtain a suitable OPG image for diseases diagnosis. The remaining part of the current paper is divided in to four sections: Section (II) is devoted to illustrate the phases of proposed method. Section (III) highlights the measurements applied for image quality. Section (IV) describes and discusses the obtained results. While the last section concludes and proffer the recommendations.

2. Basic Phases of Proposed method

This study is an attempt to provide a model that shows good responses to different kinds of noise which has an influence on the OPG images. Two efficient filters have been used in order to remove the noise. The first one is an Adaptive Median Filter which is responsible for removing the salt and pepper noise in an effective manner [9]–[11]. Not only that but there is also a tend to utilized Discrete Wavelet Transform for the purpose of disposal the other kinds of noise as a second stage, especially Gaussian noise [5], [12],[13].

Then there is an application of the morphology image processing for edges refining and Contrast Limited Adaptive Histogram Equalization (CLAHE) for the purposes of contrast enhancement on the denoised images in order to obtain an appropriate visualization and compensate the influence of the process of filtration that adds some blurring to images [14], [15].

Moreover, the adaption of such approach presents a kind of hybrid filtration, in addition to the contrast enhancement for OPG images which can be abbreviates as HFEOPG. These images can be used later on for diagnosis diseases, such as tumor and cysts detection, etc.

The algorithm for refining and improving the medical image quality presented for OPG images for better visual apparent involves of two basic phases which are named as Noise Reduction phase and Contrast Enhancement phase that are demonstrated in Figure (1).

2.1 Noise Reduction phase:

It has been noticed that an Adaptive Median Filter follow by a Discrete Wavelet Transform is used for noise reduction phase in order to eliminate noises in the medical image

Furthermore, there is an addition of mixed noises in order to examine the proposal method with other filters. To that end, salt and pepper noise, Gaussian and speckle noises have been added to the OPG images with accurate variances, as well as these noises are removed by using various filters. Given the centrality of this issue, a comparison has been made between groups of filters which are, Median Filter, Adaptive Median Filter, Discrete Wavelet Transforms in one side and a hybrid filtration discipline which consists of an Adaptive Median Filter followed by Discrete Wavelet Transform which is considered as a proposed method in noise reduction in the other side. The latest introduce better results than the other filtration techniques as appeared in the practical results of this paper, different filtration techniques in this area will be explained in the following sections.

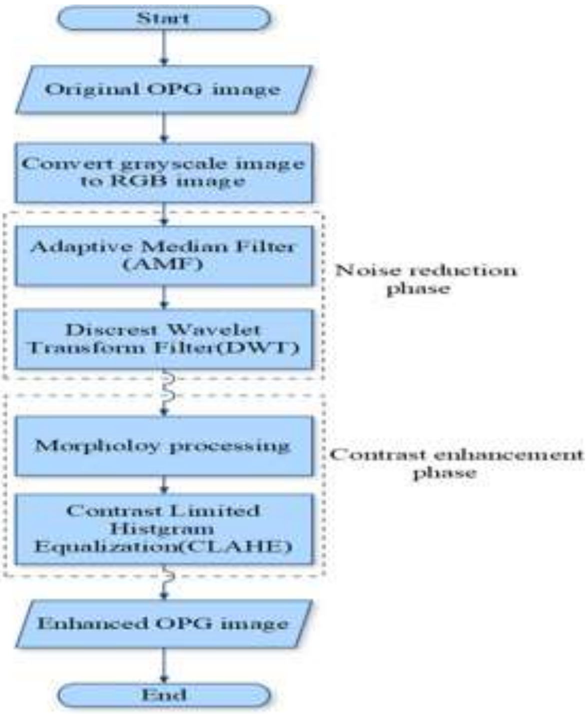


Figure 1: Demonstration of Noise Reduction and Contrast Enhancement phases of HFEOPG

2.1.1 Median Filter

There seems to be no compelling reason to argue that the median filter (MD) is considered one of the best considered non-linear filter ordered statistic digital filtering technique. There is no doubt that this technique is used to reduce noise in an image, as commonly known, replaces the corresponding pixel value with the half of the median of the gray levels inside the area of that pixel within the window. Moreover, median filter capable of reducing noise with noticeable less blurring than linear smoothing filters of the same size [10].

2.1.2 Adaptive Median Filter

As a rebuttal to this point, it could be argued that the Adaptive Median Filter (AMF) is seemed to be nonlinear order statistic filter that have the ability to handle impulse noise in more effective way than MF. The performance of the median filter can be better on condition that the spatial density of the impulse noise is not large [10]. The foregoing discussion implies that both AMF and MF use a window. However, the difference is noticed when the adaptive filter regulates the size of the filter mask due to the size of the median of gray value. Consequently, when the pixel which occurs in the center of the filter mask is ruled on to be noise, the value can be replaced by means of the median, otherwise, the current pixel value does not change.it has been noticed that AMF owns a better advantage than MF by seeking out in order to keep detail and high frequency component while smoothing non impulse noise [16].

2.1.3 Discrete Wavelet Transform

Wavelets function mathematically by representing scaled and shifted waveform copies of finite length which is called mother wavelet. It has been argued that wavelet transform is being used for the purpose of analyzing image into various frequency components of multiresolution scale [10]. The Discrete Wavelet Transform (DWT) is similar to a hierarchical subbands system. In such a system the subbands are logarithmically spread out in frequency and decomposed into limited band parts that represent subbands decomposition and perfectly reconstructed. Moreover, in the decomposition of the wavelet, signal breaks it into two classes; low pass and high pass. These classes individually carry information of original signal. Additionally, discrete Wavelet Transform decomposes the original image and transforms it into the fourth part which is normally called as LL, LH, HL, and HH as in the schematic illustrated in Figure 2-a. The LL subband can be decomposed into four subbands labeled as LL2, LH2, HL2, and HH2, as shown in Figure 2-b [10], [17], [18].

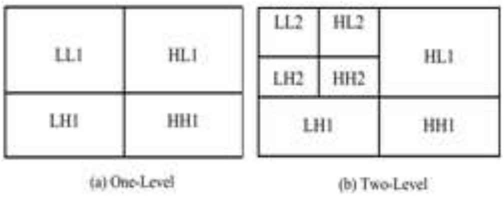
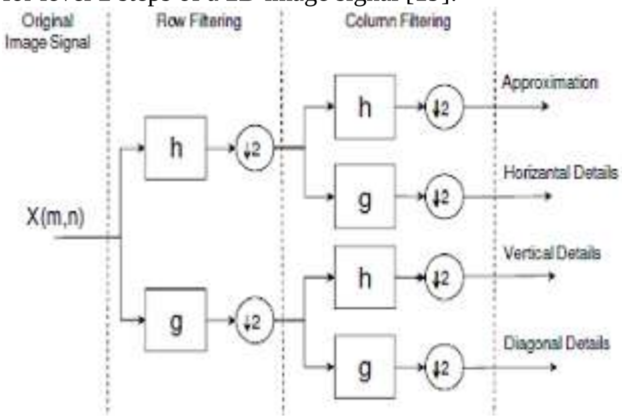
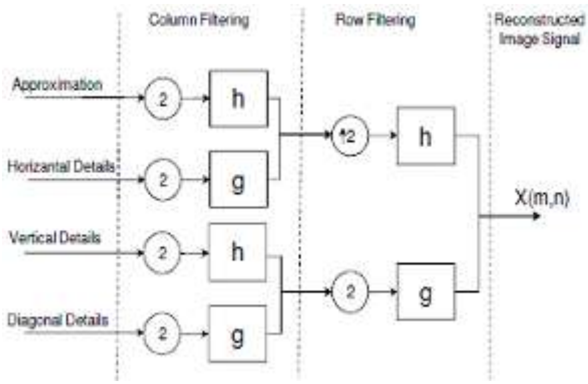


Figure 2: Discrete Wavelet Transform decomposition of image

Significantly, the LL part comes from low pass filtering in both directions and it is called the approximation which is similar to the original picture. Whereas, the remaining parts are called detailed components. Above all, it sees pertinent to say that LH arises from low pass filtering in the vertical direction, HL comes from high pass filtering in the horizontal direction and HH represents the diagonals details. Furthermore, a 2D image, N level decomposition can be performed as a result of 3N+1 different frequency. Figure (3) below illustrates the DWT decomposition and reconstruction for level 2 steps of a 2D image signal [19]:



(a)



(b)

Figure 3: Illustrates the DWT decomposition and reconstruction for level 2 for 2D image.

Thresholding is considered one of the important steps to reduce noise. The function of the thresholding is a wavelet shrinking function which determines how the threshold is implemented to wavelet coefficients. Thresholding is notably used to segment an image by setting all pixels whose intensity values are above a threshold to a foreground value and all the remaining pixels to a background value. Furthermore, thresholding is essentially divided into two categories: hard and soft Thresholding. Hard thresholding is more intuitively appealing and also it introduces artifacts in the recovered images. On the other hand, Soft thresholding is more efficient and it is used for the entire algorithm. Soft thresholding is considered as a recognized thresholding rule. Owing to its effectiveness and simplicity and visually introduce more agreeable images [11], [16].

2.2 Contrast Enhancement phase

There is a growing support for the claim that this phase comprises of Morphology image processing for edges refining and Contrast Limited Adaptive Histogram Equalization (CLAHE) for contrast enhancement which is intended for better visual appearance after noise reduction phase and smoothing process for the OPG image.

The noise reduction filters have the ability to offer smoothing in addition to few blurring to the final images, i.e. the process of such progressive phase after denoising filters is mainly to enhance the edges and highlight the high frequency components and to eliminate the remaining noise parameter.
The noise reduction filters could present smoothing and a few blurring to the resulted images, hence, the process of this improving phase after denoising filters is basically to enhance the edges and highlight the high-frequency components and to eliminate the remaining noise parameter. Next, we will explain the different enhancement techniques that we used in this paper. The various enhancement techniques will be explained in details in the following sections:

2.2.1 Morphology processing

There is no doubt that mathematical morphology is considered a kind of nonlinear filters, which is generally used in the image enhancement methods as a sharpening technique. Moreover, top-hat and bottom-hat transform is executed as a morphological processing in this algorithm, that is able to improve the features of gray scale images. The top-hat (I_{top}) transform and the bottom-hat (I_{bottom}) transform for an image illustrated in Equations (1) and (2) :

$$I_{top} = I - (I \circ b) \qquad (1)$$

$$I_{bottom} = (I \bullet b) - I \qquad (2)$$

Here, the notation ◦ denotes to the grey scale “opening” operator, while the notation • denotes to the grey scale “closing” operator and the structure element is symbolized by b. Furthermore, the opening operation is used to give emphasis to the features with the darker region of gray scales, while the closing operation is used to emphasize the features with the brighter area of gray scales. Consequently, taking into consideration the difference between the original image and it’s opening and closing versions as shown in Equation

(1) and Equation (2), obviously it has been noticed that the top-hat transform can extract the brighter features and the bottom-hat transform can extract the darker features [14]. The new enhanced image (I_{new}) is obtained after combining the image with its top-hat and bottom-hat transformed forms, as shown in Equation (3):

$$I_{new} = I + I_{top} - I_{bottom} \qquad (3)$$

According, the peaks and ridges are extracted by the top-hat transform that is eliminated by the opening process. Therefore, the addition of such features to the original image has the ability to increase brighter structure. Likewise, the bottom-hat transfer extracts the valleys and troughs which are extracted by the use of closing process. Thus subtracting such features has the ability to increase the darker structures, which means making those darker features even darker [14].
It has been notice that the use of top-hat morphological process enables the researcher to acquire more important points of the teeth, the edges, surface, in addition to size. Moreover, there is an enhancement in the background image which gets higher identification of the teeth, in addition to availability of caries. Furthermore, the purpose behind the bottom-hat process is highlighting the valleys of images. There is no doubt that such a situation creates more emphasis on the objects and leads to simplification of their particles from the background image [7].

2.2.2 Unsharp Mask

It has illustrated that Unsharp Masking (USM) enhancement process is commonly implemented algorithms for the enhancement of images appearing. It essentially enhances the edges and also heightens components of high-frequency current in the image. This technique is typically applied by using Laplacian operator. Generally speaking, USM is an image sharpening method. Its term "unsharp" is derived from the fact that this scheme has been used in its process a blurred, that earnings "unsharp", positive image in order to produce a mask of current original image. The bring about the unsharped mask is then added to the negative form of the image, producing an image that is less blurry and further sharpening than the original one [20].

Furthermore, USM filter generates an edge image g(x,y) from input image f(x,y) as shown in Equation (4).

$$g(x,y) = f(x,y) - f_{smooth}(x,y) \qquad (4)$$

Where, $f_{smooth}(x,y)$ is considered a smoothed image form of f(x,y) which is created by a Gaussian mask of an obligatory radius and convolves it with the original image so it causes blurring the image.

The edge images from the result of subtracting input image from low pass signal could be utilized for images sharpening by adding it backward into the input signal, as illustrated in Figure (4). This function is represented as follows:

$$f_{sharp}(x,y) = f(x,y) + k*g(x,y) \qquad (5)$$

Where, k is a scaling constant, values for k (k≥0). Generally, When k>1, the process is referred to as high-boost filtering. In the research process, k=1 is applied [21].

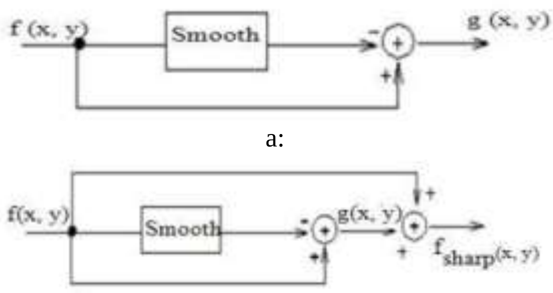


Figure 4: Unsharp filtering Operation

2.2.3 Contrast Limited Adaptive Histogram Equalization

It is important to take into consideration the fact that histogram processing is consideration to be one of the most unique techniques that are typically used in enhancing an image. As was previously stated, an Adaptive Histogram Equalization (AHE) has the ability to calculate different histograms corresponding to various image regions, then using these regions of images in order to reorganize value of the image. Accordingly, it is more appropriate for those images that have low contrast tp work in improving the images viewing [21]. The previously mentioned AHE can be defined as an image processing technique which has a great role in the improvement of the images contrast.

Furthermore, the histogram equalization HE maximizes the image noise. In addition to enhancing its visual patchiness. Many alternatives of HE have been proposed in order to solve such problems [15]. Moreover, CLAHE is considered one of the improved versions of AHE. Importantly, both of them overcome the HE limitations. It has been argued that CLAHE has the ability to enhance the contrast of the images, in particular with the availability of close contrast values to the image. Moreover, CLAHE seems to add a progress to the local contrast of images [14], [15], [23].

The current research appears to validate such a view that pixels intensity may be better distributed on the histogram. Thus, the regions which own low contrast seems to have a higher gain contrast without influencing the global contrast [23].

There is a growing support for the claim that algorithm divides the image into small non-overlapping regions which could be called tiles, so the histogram equalization is applied to every signal tile. Additionally, every contrast in tiles can be increased so that the histogram which has pixel counts the bin over the clip-limit and they are re-delivered in an equal way, as illustrated in Figure (5). There is a repetition in this process until reaching a degree of no histogram of pixels go over the clip-limit. Notably, there is an equalization between the histogram of the output of this small region and the specified histogram. So that neighboring tiles are inserted by using bilinear interpolation for the purpose of reducing the artificiality that has the ability to bring boundaries [14], [23].

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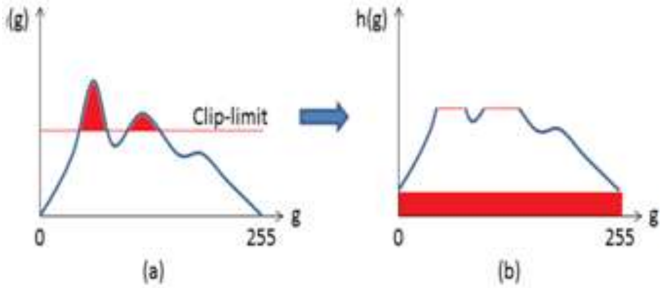

The original histogram The redistributed histogram

Figure 5: The illustration of histogram redistribution in CLAHE

Nevertheless, noises may be amplified by AHE in a homogeneous area, introduces artifacts and lose out the image details which are caused by the large slope of the mapping function. Quite the opposite, CLAHE constrains the slope of the mapping function which has the ability to reduce the undesired amplification of noise in the homogeneous region. Meanwhile, there are many homogeneous regions in OPG images, thus the CLAHE is considered appropriate for enhancing medical images in general [5], [14].

3. The Measurements of Image Quality

Well known Measurable methods have been used for assessing and comparing image quality. Peak Signal to Noise Ratio (PSNR), Structural Similarity Index Matrix (SSIM), Absolute Mean Brightness Error (AMBE), and Enhancement Measurement Error (EME) are the most commonly used Image Quality Measurements.

3.1 Peak Signal to Noise Ratio (PSNR)

It has been illustrated that PSNR is generally used for measuring the quality of the handled image with respect to the original input image. PSNR is explained in terms of logarithmic decibel scale. In general; higher PSNR value indicates that the output handled image is acquiring the better quality. Moreover, PSNR is defined in terms of Mean Square Error MSE as follows [22].

$$PSNR = 10\, log_{10}(\frac{MAX_i^2}{MSE} \qquad (6)$$

Where MAXi2 is the maximum possible pixel intensity value when the pixel is represented by 8 bits its value is 255. In the same way, MSE is defining as follows:

$$MSE = \sqrt{\frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}[I(i,j) - K(i,j)]^2} \qquad (7)$$

Where I(i,j) represent input image and K(i,j) represents output image.

3.2 Structural Similarity Index Matrix (SSIM)

SSIM is used for measuring the similarity between two images X and Y and calculated as shown [14]:

$$\text{SSIM}(X,Y) = \frac{(2\mu_x\mu_y+c_1)(2\sigma_{xy}+c_2)}{(\mu_x^2+\mu_y^2+c_1)(\sigma_x^2+\sigma_y^2+c_2)} \qquad (8)$$

Where μx the average of x; μy the average of y; σx the variance of x; σy2 the variance of y; σxy the covariance of x and y; c1 and c2 are constant. SSIM is valuable for anticipating the perceived quality of the image [14].

3.3 Absolute Mean Brightness Error (AMBE)

The absolute mean brightness error is definite by the equation:

$$\text{AMBE}(x,y) = |Xm - Ym| \qquad (9)$$

Where, Xm means intensity value of input image x ={x(i,j)} and Ym means intensity value of output image y={y(i,j)} is designed for improving better brightness preservation. So, AMBE should be the smallest value [24].

3.4 Enhancement Measurement Error (EME)

Enhancement measurement error (EME) separates the input image into n1n2 non-overlapping sub blocks. The EME value is calculated as follows:

$$EME = \frac{1}{n_1 n_2}\sum_{i=1}^{n_1}\sum_{i=1}^{n_1} 20ln\frac{\max(x_i,j)}{\min(x_i,j)} \qquad (10)$$

Where max (xi,j) and min (xi,j) are the maximum and minimum grey levels in block xi,j respectively. The Greater value of EME is having the more quality of the OPG input image [22].

4. Results and Discussion

The foregoing discussion implies that, four OPG X-ray images have been used, as shown in Figure (5-a), in order to evaluate the performance of the denoising process and contrast enhancement individually since the reduction of noise and contrast improvement are considered two separate phases. For noise reduction phase, MF, AMF and DWT are considered. The proposed method is taken in to consideration after evaluating the hybrid filtration technique by choosing the best performance in comparison with the previously mentioned filters individually.

Above all, the test is applied by adding three types of noise (Salt-and-pepper, Gaussian, and Speckle noise) to the research sample OPG images. Moreover, a mixture of these types of noise is added with noise variances of about 10% for salt and pepper and (0.01) for Gaussian and speckle noise respectively. Each of the obtained results is compared with the proposed method.

In order to make the comparison of noise in a reduction phase, two evaluation parameters are used, which are PSNR and SSIM.

Notably, the images are tested with mixed noise. Table (1) and Table (2) illustrate PSNR and SSIM of the results for different denoising methods. The proposed method has the highest PSNR and SSIM for denoising the mixed noise in comparison with the other methods. Figure (6) demonstrates the denoised results after adding the mixed noise.

Table 1: PSNR (dB) of the denoised images with mixed noise

Images	MF	AMF	DWT	HEAEOPG
1	30.98	31.21	30.20	31.74
2	31.05	31.29	30.11	31.78
3	31.80	32.04	30.92	32.62
4	30.27	30.39	29.25	30.96
Average	31.02	31.23	30.12	31.78

Table 2: SSIM of the denoised images with mixed noise

Images	**MF**	**AMF**	**DWT**	**HEAEOPG**
1	0.8826	0.8835	0.6431	**0.9140**
2	0.8915	0.8963	0.6367	**0.9184**
3	0.9120	0.9231	0.6521	**0.9275**
4	0.8650	0.8677	0.6231	**0.8862**
Average	0.8877	0.8926	0.6387	**0.9115**

For contrast enhancement evaluation, measurement comparisons are used. Figure (7) shows the enhanced OPG images by using different techniques. Another key point is that four techniques are intended for better evaluation of contrast enhancement. AHE, CLAHE, USM prior to CLAHE and Morphology before CLAHE.

From the visual comparison, it has been noticed that the AHE results have high contrast images as shown in table (3), which are not the preferred effects that are needed it for further purposes such as diagnosis for dental diseases; quite the opposite, both CLAHE and USM-CLAHE method are capable of achieving visually acceptable results. As well as, applying Morphology processing before CLAHE, HFEOPG can obtain more details such as instance edges and textures than the other approaches.

Preferably, the contrast enhancement had better preserve the equivalent mean brightness of an image. Thus, the lower value of AMBE is desired. Table (3) shows that the AHE has much higher AMBE than the relating methods because of the high contrast problematic in the homogeneous areas. The proposed method obtained a little lower AMBE than CLAHE and USM-CLAHE, therefore, another index is worked; i.e. EME to compare the performance of contrast enhancement. This implies that the higher value of EME has better-improved contrast of OPG image. Table (4) shows that HFEOPG obtained the higher EME than the original input images and the images enhanced by the others approach. Table (3) AMBE of the different methods for contrast enhancement.

Table 3: AMBE of the different methods for contrast enhancement

Images	AHE	CLAHE	USM- CLAHE	HEAEOPG
1	41.789	28.773	27.804	27.212
2	38.799	31.053	29.953	28.678
3	40.548	30.846	28.125	27.810
4	33.164	26.235	26.874	25.725
Average	38.575	29.227	28.189	27.356

Table 4: EME comparisons

Images	Original image	CLAHE	USM- CLAHE	HEAEOPG
1	13.935	50.988	51.324	57.373
2	12.686	50.666	52.872	55.372
3	11.210	42.549	45.306	46.128
4	10.956	40.962	44.503	47.651
Average	12.197	46.291	48.501	51.631

5. Conclusion

In the current paper, it has been proposed that there is an algorithm with capability of noise reduction and contrast enhancement for OPG images. The previously mentioned noise reduction phase consists of an adaptive median filters and desecrate wavelet transform filter to deal with the mixed noise. The available evidence seems to suggest that the image improvement phase consists of morphology image processing followed by CLAHE in order to an enhance the contrast with more details. Moreover, the experiments show that the proposed method is able to obtain an average PSNR 31.78 dB and an average SSIM 0.9115 in the mixed noise; for the contrast enhancement, additionally, the proposed method is able to obtain higher EME values than the other techniques, which means that the images that are enhanced by the proposed method have better contrast improvement.

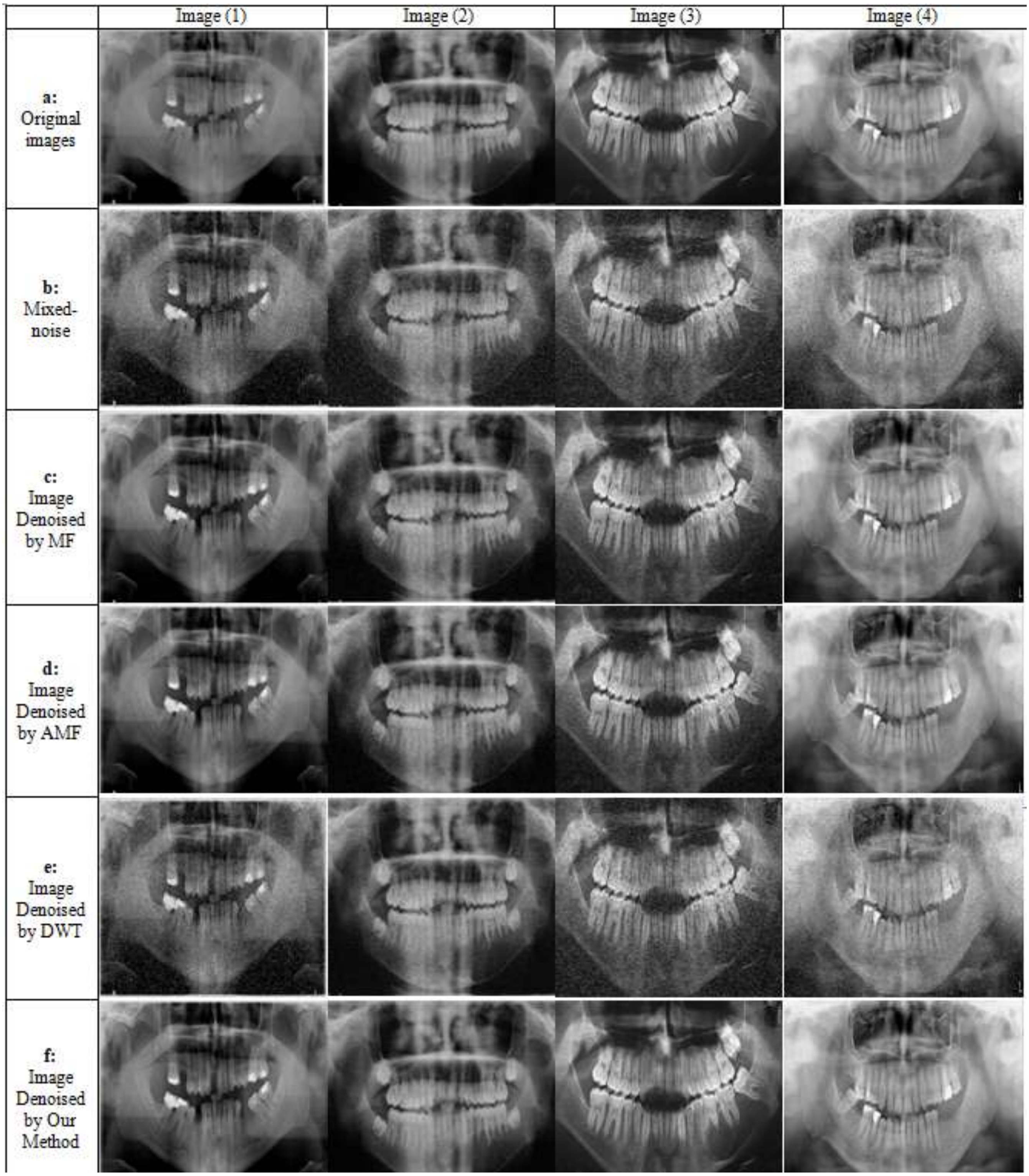

Figure 6: Image denoising results. (a) The original images. (b) The image with mixed noise. (c) Image denoised by median filter. (d) Image denoised by AMF filter. (e) Image denoised by DWT. (f) Image denoised by DWT_AMF. (g) Image denoised by our method.

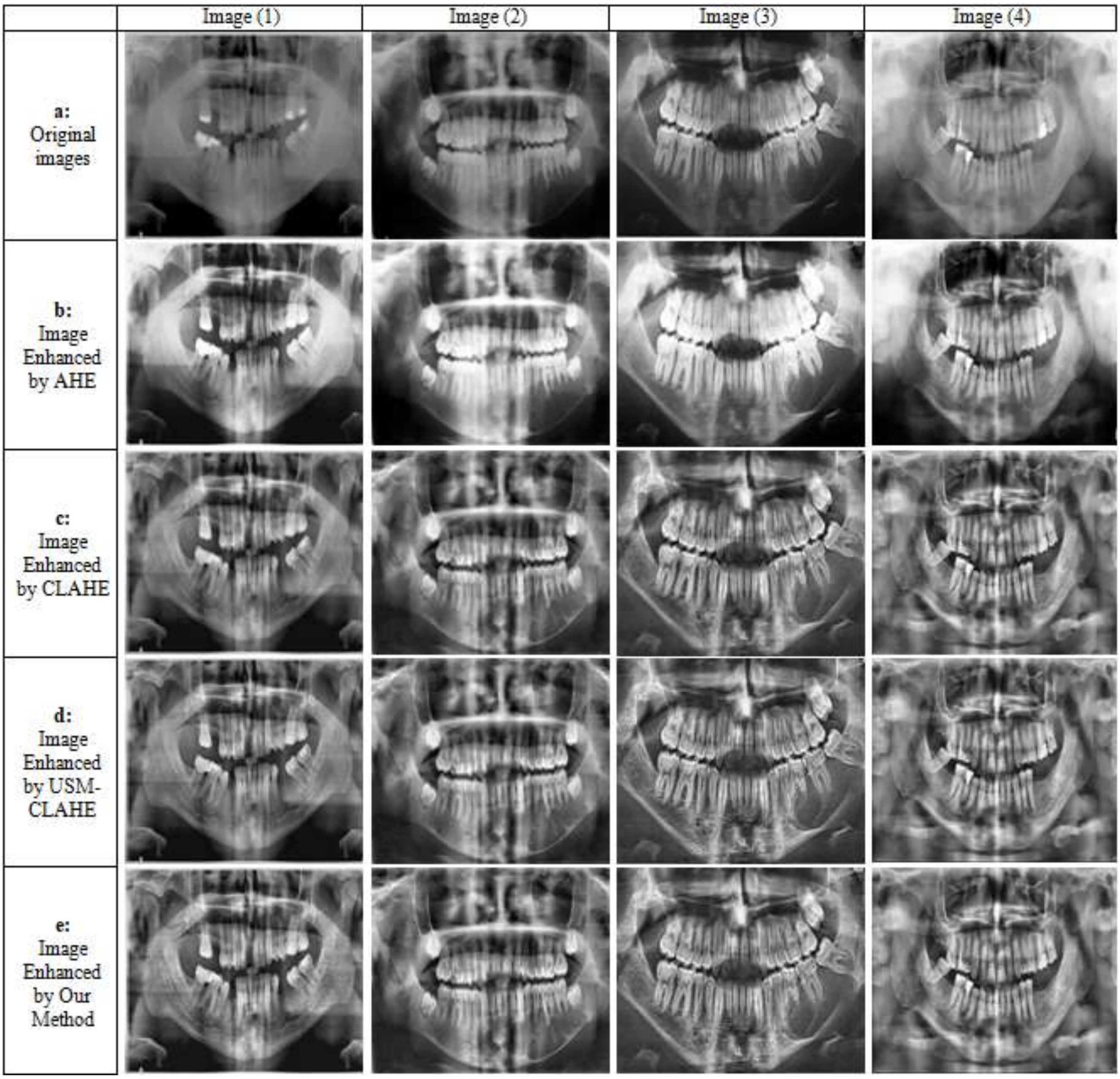

Figure 7: Image Enhancement results. (a) The original images. (b) Image Enhanced by AHE. (c) Image Enhanced by CLAHE. (d) Image Enhanced by USM- CLAHE. (e) Image Enhanced by Our Method.

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