Dental Image Enhancement Using Wavelet Decomposition and Reconstruction

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Abstract—The use of dental radiography techniques like CBCT, X-RAY etc have increased the diagnosis efficiency, but the images contain noise and are low contrast. Therefore de-noising and enhancement are very important factors in any subjective evaluation of the quality of images. In this paper a wavelet based enhancement technique is introduced. The input image is decomposed into different sub-bands by means of Discrete Wavelet Transform (DWT). Stationary Wavelet Transform (SWT) is introduced as an intermediate stage to enhance the image. Then the high frequency sub-bands of both DWT and SWT are added together. These high frequency sub-bands are then interpolated. A new enhanced image is obtained by using inverse DWT (IDWT). De-noising is done by means of median filter. The whole work has been done on the MATLAB.

Index Terms—De-noising using Median filter, Dental images, Enhancement, Discrete wavelet transform, IDWT, PSNR Stationary wavelet transform.

I. INTRODUCTION

Digital Image Processing is widely implemented technique in Medical Imaging. Various branches of medical science are using digital image processing as a comprehensive technique to visualize and extract more details from the image. Quality enhancement of medical images is to be performed with the help of various image processing methods. Presently, the first step in disease diagnosis via imaging modalities relies mostly on x-ray images. This is also true for the field of dentistry where x-ray images are persistently used to assist dentists in deciding the pertinent treatment for patients.

Digital images are corrupted by different types of noises during its acquisition and transmission by numerous effects. Particularly, medical images are likely disturbed by a complex type of addition noise depending on the devices which are used for capturing and storing them. No medical imaging devices are noise free. Usually, the additional noise in medical images reduces the visual quality that complicates diagnosis and treatment. Noise reduction and enhancement are two important aspect of image processing. Noise reduction is used to remove the noise without losing detail present in the images. This process of recovering the signal that has been corrupted by noise is called de-noising. Also the image has to be enhanced in order to improve the diagnostic ability. It is very important to enhance the medical images to expose the hidden information in it.

Usually the intra-oral digital radiographs are of low image quality due to low dose usage of x-ray. The idea behind low dose usage of x-ray is related to its effect to patient’s health. So we need to improve the quality of these images. Image enhancement and de-noising are some of the image processing techniques acceptable for this purpose.

The x-ray images are typically corrupted by Poisson noise, salt and pepper noise and speckle noise [8]. The presence of noise will severely harm the knowledge or data contained within the original image. It also decreases the resolution and contrast of the image. Due to this effect low contrast lesions may not be clearly detected in the diagnostic phase. So the noise removal from medical images is very important task. In this project, our aim is to de-noise and enhance dental x-ray images to form better images for analysis by human or machine.

The elimination of salt-and-pepper noise is very necessary because the occurrence of noise will severely harm the knowledge or data contained within the original image. The only and the traditional way to remove salt-and-pepper noise is by windowing the noisy image with a standard median filter. Median filters are used because they provide very good noise reduction capabilities without effectively reducing the image sharpness [4]. Enhancement of the de-noised image is then performed in the wavelet domain, where the DWT [2] and SWT [3] decompose the low resolution image into various frequency sub-bands. The sub-bands are Low Low (LL), Low High (LH), High Low (HL) and High High (HH). The SWT is used to preserve the high frequency content in the image. SWT is similar to DWT but it does not use down-sampling; hence the sub-bands will have the same size as the input image. The dwt sub-bands are then interpolated by a factor of 2. The interpolated high frequency sub-bands and the SWT high frequency sub-bands are added together to produce the estimated sub-bands LH, HL and HH. The new corrected
high frequency sub-bands can be interpolated further by a factor of $\alpha/2$ for higher enlargement. Instead of LL sub-band the input image is used as LL sub-band. Then Inverse wavelet transform is carried out to produce the high resolution image [5].

This work mainly put forward an enhancement technique which creates sharper de-noised image. The proposed technique has been compared with two conventional image resolution enhancement techniques, which include bicubic interpolation [9] and wavelet zero padding [7], [9]. The quantitative and qualitative experimental results shows that the proposed technique over performs those conventional techniques. Quantitative evaluation is done by means of PSNR calculation. The whole work has been done on MATLAB.

The remaining paper is organized as follows. In section 2 proposed methodology is presented. Experimental results and discussions are given in section 3. Finally the concluding remarks are given in section 4.

II. PROPOSED METHODOLOGY

The aim of this paper is to enhance the low resolution dental images. The block diagram of the method is shown in Fig.1.

![Fig.1 The Block diagram for the proposed method](image)

A. Image Acquisition

The x-ray machine is interfaced to a computer and the dental radiographic images are obtained as digital images. These images are corrupted by some noise during its acquisition. So we need to de-noise these images before enhancement.

B. Image De-noising

Usually the x-ray images are corrupted by Poisson noise, salt and pepper noise and speckle noise. These noises results in minute grey scale variations within the image. To remove these kinds of noises better choice is to use a median filter. Median filter is an order statistic filter [1]. This is basically a nonlinear spatial filter, whose response is based on ordering (ranking) the pixels contained in the image area encompassed by the filter, and then replacing the value of the central pixel with the value determined by the ranking result. As its name implies, median filter replaces the value of a pixel by the median of the gray levels in the neighborhood of that pixel [1]. Because this filtering is less sensitive than linear techniques to extreme changes in pixel values, it can remove noise without significantly reducing the sharpness of an image. A 3x3 median filter is used over here.

C. Image Enhancement

Resolution of an image is its clear perception to the viewer. This paper put forward a wavelet approach for resolution enhancement of dental digital x-ray images. The resolution enhancement of image mainly deals with the process of conversion from lower resolution (LR) to a higher resolution (HR). HR means that the density of pixel per unit area in the image is high, and hence an HR image can offer more details.

This paper gives a wavelet approach for resolution enhancement of dental digital x-ray images. Here a single level DWT (with Daubechies 9 as wavelet function) is employed to decompose an input image into different sub-and images [5]. The high frequency components of the input image are contained in the three high frequency sub-bands (LH, HL, and HH) of the input image. Bicubic interpolation with enlargement factor of 2 is applied to high frequency sub-bands of the image. Down sampling each of the DWT sub-bands gives rise to information loss in the respective sub-bands. SWT [3] is introduced to minimize this loss. The interpolated high frequency sub-bands and the SWT high frequency sub-bands have the same size. They are added with each other to obtain estimated sub-bands. These new high frequency sub-bands are further interpolated or higher enlargement. In the wavelet domain, the low resolution image is obtained by low pass filtering of the high resolution image [6]. In other words, low frequency sub-band is the low resolution of the original image. Therefore, instead of using low frequency sub-band, which contains less information than the original high resolution image, we use the input image for the interpolation of low frequency sub-band image. Finally IDWT [5] is applied to obtain the high resolution dental image. Fig. 2 illustrates the block diagram for the proposed dental image resolution enhancement technique.
D. PSNR Calculation

Improving the visual quality of dental digital x-ray image can be subjective. Therefore it is necessary to establish quantitative measures to compare the effects of image enhancement algorithms on image quality. So we calculate the PSNR of the enhanced image. PSNR is the Peak Signal-to-Noise ratio in decibels (dB). It is most easily defined by the mean squared error (MSE).

\[
PSNR_{\text{db}} = 20 \log_{10} \left( \frac{\text{Max. pixel. Value}^2}{MSE} \right) \tag{1}
\]

MSE is the square of the difference between the input image I(i,j) and output image O(i,j) and is given by the following equation.

\[
MSE = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i, j) - O(i, j)]^2 \tag{2}
\]

Where m and n are the number of pixels of the two images respectively.

For post processing, the input image is to be converted in to gray scale format. After converting image in to gray scale, salt and pepper noise is added in the resultant image.

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

Fig. 3 shows the experimental results obtained by applying the proposed methodologies and Fig. 4 gives the comparison of the proposed resolution enhancement method with conventional methods.

In Fig. 3 Noisy, LR dental x-ray image is shown in (a), which is the input image for processing, denoised, LR image obtained after median filtering is shown in (b) and the HR image using the proposed wavelet decomposition technique is shown in (c).

Fig. 4 gives the performance evaluation of the proposed method in terms of peak signal to noise ratio (PSNR).
Fig. 4 Performance evaluation of the proposed method in terms of PSNR.

Fig. 5 shows that the enhanced image obtained using proposed technique in (c) is much better than the image obtained using bicubic interpolation in (a) and the image obtained using WZP in (c).

To show the effectiveness of the proposed method over the conventional image resolution enhancement techniques, a comparison of the PSNR performance is given in Table I. These results indicate that the proposed technique has much higher performance than the conventional image resolution enhancement techniques.

<table>
<thead>
<tr>
<th>Techniques</th>
<th>PSNR</th>
</tr>
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<tbody>
<tr>
<td>Bicubic Interpolation</td>
<td>24.92</td>
</tr>
<tr>
<td>WZP</td>
<td>29.26</td>
</tr>
<tr>
<td>Proposed method</td>
<td>32.78</td>
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</tbody>
</table>

TABLE I Comparison of PSNR values

IV. CONCLUSION

This work proposed a denoising and resolution enhancement technique for dental radiography images using wavelet decomposition and reconstruction. Salt and pepper noise present in image is removed by windowing the noisy image with a median filter before performing the enhancement process. It clear that better performance is achieved using the proposed technique than the conventional techniques. Quantitative assessment of the image quality is performed by means of peak signal to noise (PSNR) calculation. The enhancement will improve the accuracy of dental X-ray image and will be helpful to dentist for analyzing the symptoms of the patients. This work can be further extended to find a novel contrast enhancement method that still improves the quantitative measures.

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REFERENCES
