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WAVELET COEFFICIENT MAPPING FOR ENHANCEMENT OF CHEST X-RAY IMAGES

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Abstract – An approach to image enhancement of digital chest radiographs is described. The method is to employ various non-linear mapping functions to different scale levels at the transform domain. The mapping functions are used to project a set of discrete wavelet transform (DWT) coefficients to a new set of DWT coefficients. The mapped coefficients are then inverse wavelet transformed. Our preliminary results strongly suggest that the proposed method offers considerably improved enhancement capability over the fast Fourier transform method and the conventional DWT method.

Keywords: medical imaging, wavelet transform, chest x-ray images

1. INTRODUCTION

Recently the discrete wavelet transform (DWT) has been recognized as a powerful image-processing tool for image enhancement, image compression, image segmentation, image denoising, etc[1-8]. Commonly used image enhancement techniques take a DWT of an image, modify the DWT coefficients in the transform domain, and then transform the modified coefficients back [9,10]. Lemmetti ***et. al.*** proposed an enhancement technique for x-ray images [11]. They modified the DWT coefficients using a pointwise nonlinear transform. The detail coefficients over a threshold were modified by a root function and the approximation coefficients are linearly attenuated [12].

In this paper we propose a simple method for image enhancement based on the DWT. The method is to employ various non-linear mapping functions to different scale levels. The mapping functions are use to project a set of DWT coefficients to a new set of DWT coefficients. The mapped coefficients are then inverse wavelet transformed.

The goal of this work is to enhance x-ray chest images to achieve better visibility of the observed phenomena to human observer (radiologist). To validate the effectiveness of the proposed method, we compare the results obtained by the proposed method to that obtained by the conventional fast Fourier transform (FFT) method and by the conventional DWT method.

2. METHOD

2.1. Wavelet transform

The wavelet transform [13-16] is defined as follows:

$$w_k^j = \int f(x)\psi\left(\frac{x}{2^j} - k\right)\mathrm{d}x, \tag{1}$$

where ψ is the transforming function and is called the mother wavelet, $f(x)$ is the original signal. j and k are scale and translation parameters, respectively.

However, it is often to analyze any signal by using an alternative approach called the multiresolution analysis (MRA). The MRA is generally expressed as follows.

$$f(x) = \sum_{j=1}^{\max} g_j(x) + f_{\max}(x)\cdot \tag{2}$$

That is, the original signal $f(x)$ can be expressed by the sum of the approximated function $f_{\max}(x)$ at maximum decomposition level and the detail components $g_j(x)$ (j=1,2,…,max).

2.2. 2-D wavelet transform for image processing

Fig. 1 shows a layer presentation of 2-D WT for an image. w^j_V,, w^j_H, and w^j_D represent the detail components in the vertical, horizontal and diagonal directions at level j, respectively. s^j_S refers to the scaling (approximation) component at level j. The approximation and detail components correspond to the low-frequency and high-frequency components, respectively, in spatial frequency domain. If an image is decomposed to level *max*, level 1 contains the component of the highest frequency inherent in the image, and level *max* contains the component of low frequency inherent in the image. The DWT coefficients of the respective frequency bands contain the localization information of the original image.

It is known that the Fourier transform (FT) gives what frequency components (spectral components) exist in the image. The coefficients obtained from the FT only provide frequency information. They do not give space localization information for a certain image pattern (edge or noise). For example if the edge and the noise have the same frequency. In this case if enhancement operation applies to the coefficients of the frequency component, both the edge and the noise are enhanced. In contrast, the DWT gives both the frequency information and localization information. In general, those DWT coefficients having greater values represent edges. On the contrary, those DWT coefficients having small values represent the noise.

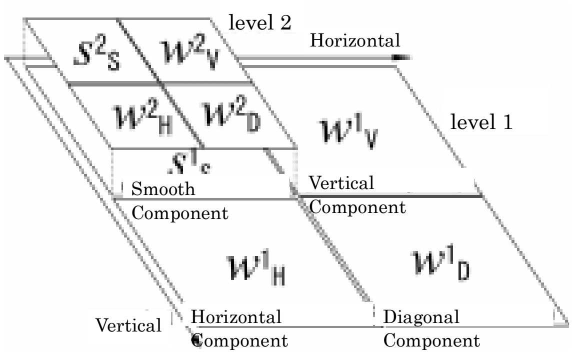

Fig.1 Layer presentation of 2-D wavelet transform.

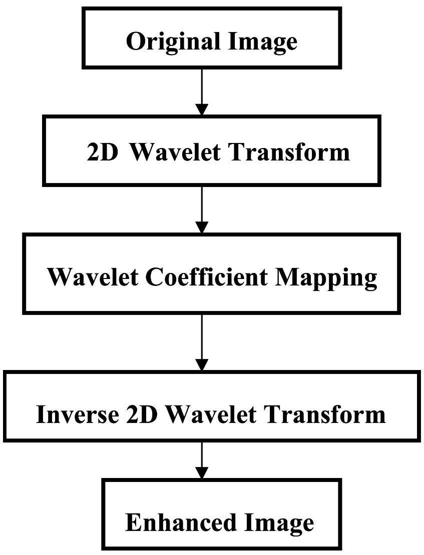

Fig. 2 Flow chart of image enhancement using the wavelet transform.

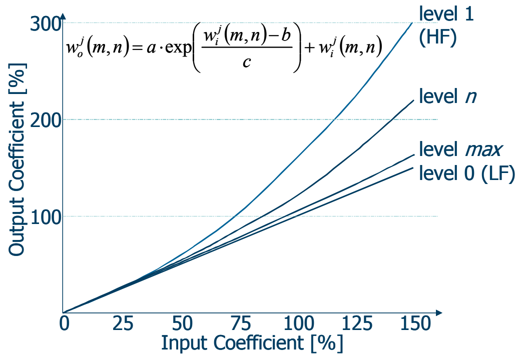

Fig.3. The mapping of input coefficients to output coefficients.

2.3. Image enhancement

After 2D wavelet transformation, the DWT coefficients are weighted using mapping functions and then the weighted DWT coefficients are inversed. This operation results in the enhancement of image edges. Therefore the selection of weighting values for the DWT coefficients is of importance. Fig. 2 shows the flow chart of the image enhancement using the proposed wavelet coefficient mapping.

The mapping function was determined based on the following considerations: (a) in the case of detail components at a specific level, the coefficients having great values are weighted, since they carry more effective information, (b) the coefficients at low levels are heavily weighted, since they carry edge information and (c) the scaling coefficients of level *max* are not manipulated for preventing image distortion.

The input coefficient $w_i^j(m,n)$ of level j at position (m,n) is manipulated using (1).

$$w_0^j(m,n) = a \cdot \exp\left(\frac{w_i^j(m,n) - b}{c}\right) + w_i^j(m,n) \quad , \qquad (3)$$

where $w_o^j(m,n)$ is the coefficient after mapping.. The constants a, b and c are determined depending on the extent of enhancement. In practice, (4) is used instead of (3).

$$w_0^j = a \cdot \exp\left(\frac{w_i^j - b}{c}\right) + w_i^j \quad [\%] \quad , \qquad (4)$$

where w_i^j and w_o^j are input and output coefficients, respectively. The values of the coefficients are expressed by percentage for the ease of computation. In the present study the value of constant a is computed using (5). The values of the constants b and c used are 25 and 24.94.

$$a = (\max - \text{level} + 1)/\max \qquad (5)$$

The curves in Fig. 3 representing the mapping functions show that the wavelet-coefficient mapping is non-linear and are satisfied with the three considerations described above.

3. RESULTS

Fig. 4 shows an original x-ray chest image and its processed images. Fig. 4(a) is an original chest image. Fig. 4(b) is the processed images using the proposed DWT method. Fig. 4(e) is the magnified image of the indicated subimage shown in Fig. 4(a). The image in Fig. 4(f) is the magnified image of the marked areas processed by the proposed DWT method. The size of the magnified image is 120×120 pixels. It is noted from the images that our proposed method could enhance the edges of the ribs, bronchus, and pulmonary vessels.

In order to verify the effectiveness of our proposed method, the results of a FFT-based method and a conventional DWT-based method were compared to that obtained using the proposed method. The image in Fig. 4(c) is the resultant image after applying the FFT-based method. The magnified image of the corresponding area is shown in Fig. 4(g). We noted that the image obtained by using the proposed DWT method is sharper and less noise as compared to the image obtained by using the FFT-based method.

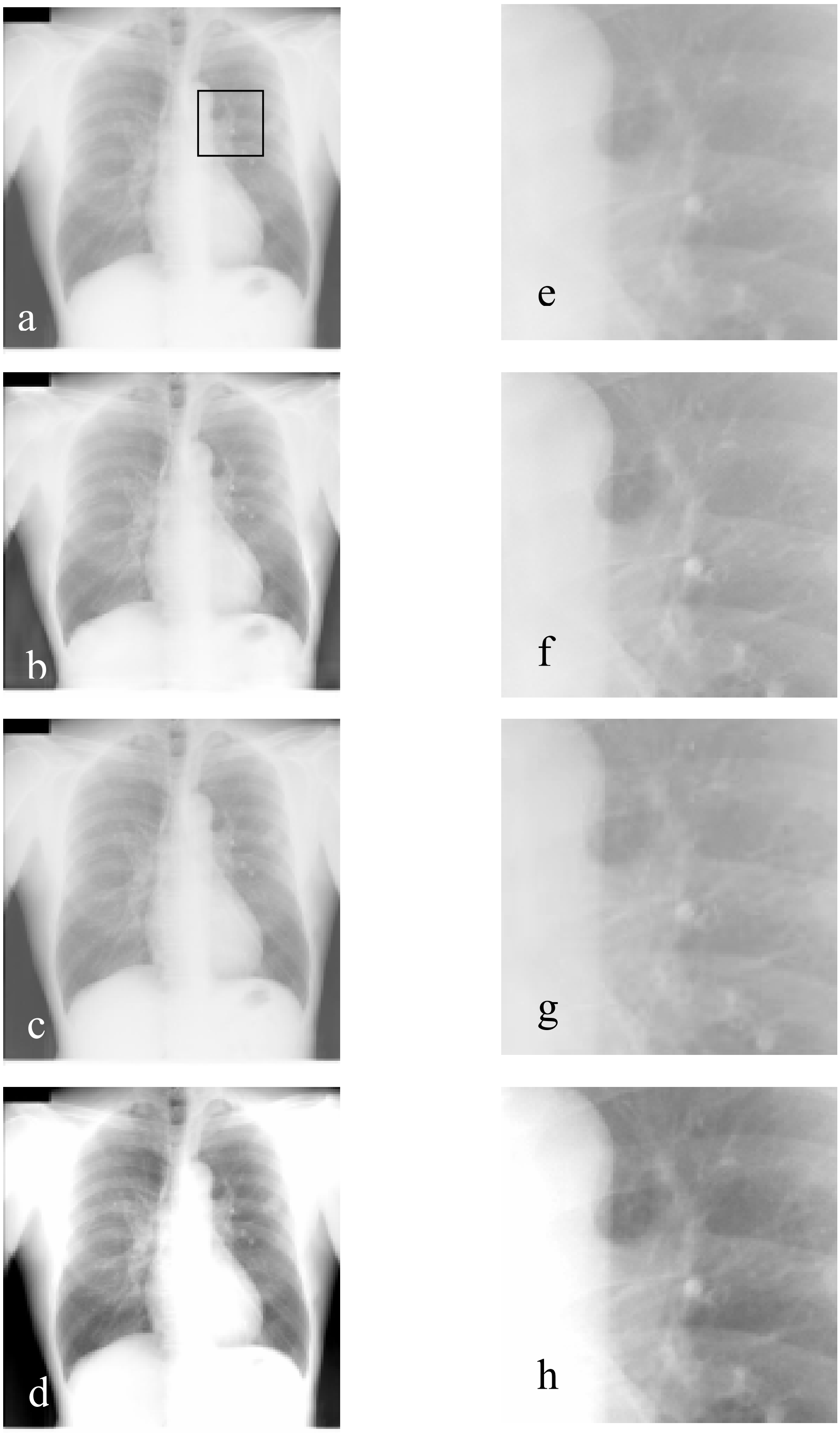

Fig. 4 (a) An original image. (b) Processed image using the proposed DWT method. (c) Processed image using the FFT method. (d) Processed image using a conventional DWT method. (e) Magnified image of the indicated subimage on (a). (f) Part of magnified image on (b). (g) Part of magnified image on (c). (h) Part of magnified image on (d).

The image in Fig. 4(d) is the resultant image after applying a conventional DWT-based method. The magnified image of the corresponding area is shown in Fig. 4(h). The conventional DWT-based method is briefly described as follows: After wavelet transformation, the coefficients of all components at all levels are multiplied by a constant, for example, 2, and then inverse wavelet transformed. It is noted from Fig. 4(h) that both the signal and noise are enhanced. It results in the failure of visually discriminating small change of gray levels, for example, edges of small vessels. In contrast, using the proposed DWT method, lower multi-resolution levels, which contain edge information is significantly enhanced, while higher multi-resolution levels, which contain approximation component information is insignificantly enhanced.

4. CONCLUSION

We proposed a wavelet-based method for the enhancement of medical images. In the proposed method non-linear mapping functions are introduced for weighting wavelet coefficients when multi-resolution levels are low and absolute values of the wavelet coefficients are great, thereby resulting in edge enhancement of images. This method was applied to chest radiographic images. The results were compared to the FFT-based and a conventional DWT-based methods. The results demonstrated that edges of the ribs, bronchus, and pulmonary vessel could be enhanced by using the proposed method without a significant enhancement of noise

However, our performance comparison in the current study was performed visually. Quantitative evaluation is required and is in progress.

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