ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 2, Issue 7, July 2013

A Survey of Medical Image Enhancement Based on Wavelet Transform

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***Abstract-* Low contrast and poor quality are main problems in the production of medical images. By using the wavelet transform and Haar transform, a novel image enhancement approach is proposed. First, a medical image was decomposed with wavelet transform. Secondly, all high-frequency sub-images were decomposed with Haar transform. Thirdly, noise in the frequency field was reduced by the soft-threshold method. Fourthly, high-frequency coefficients were enhanced by different weight values in different sub-images. Then, the enhanced image was obtained through the inverse wavelet transform and inverse Haar transform. Lastly, the image's histogram was stretched by nonlinear histogram equalisation. Experiments showed that this method can not only enhance an image's details but can also preserve its edge features effectively.**

Index Terms— **Image noise, Denoising, Median filter, Wiener Filter, ICA.**

I INTRODUCTION

Medical image enhancement technologies have attracted much attention since advanced medical equipments were put into use in the medical field. Enhanced medical images are desired by a surgeon to assist diagnosis and interpretation because medical image qualities are often deteriorated by noise and other data acquisition devices, illumination conditions, etc. Also targets of medical image enhancement are mainly to solve problems of low contrast and the high level noise of a medical image. Medical image enhancement technologies have attracted many studies, mainly on grey scale transform and frequency domain transform. Studies of frequency domain transform mainly concentrate on the wavelet transform, and histogram equalization is a quite typical method of image enhancement in the spacial field. The wavelet transform is a time-frequency analysis tool developed in the 1980s, which has been successfully applied in the image processing domain after Mallat [1] presented the fast decomposition algorithm. There are many image enhancement methods based on wavelet transform, such as Lu et al.[2], Yang and Hansell [3], Fang and Qi [4], Zhouet al. [5], Wu and Shi [6], etc. In these papers, methods of image enhancement based on wavelet transform were proposed. However, we cannot obtain more high-frequency information only through multi-scale wavelet transform. An image's different scale detail information can be obtained through wavelet transform, but there will be some high-frequency information hidden in high-frequency sub-images of wavelet transform. If we decompose these high-frequency sub-images, we can obtained more image high-frequency information which can help us to enhance a medical image effectively. Also, we can obtain a better enhancement image if we use both spacial field and transform field procession to enhance an image. In addition, we should remove or reduce noise for the reason that there are lots of noise in high-frequency sub-images. Presented in this Letter is a novel approach which is used to enhance a medical image based on wavelet transform, Haar transform and nonlinear histogram equalization

II WAVELET ANALYSIS

The wavelet transfonn is defined as follows

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

where 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.

$$f(x) = \sum_{j=1}^{\max} g_j(x) + f_{\max}(x) \quad , \qquad (2)$$

That is, the original signal f(x) can be expressed by the sum of the approximated function f,,(x) at maximum decomposition level and the detail components g , (x) (j=1,2 ,..., ma).

III METHOD

A. Two-Dimensional Wavelet Transform for Image Processing

The idea is that we decompose a medical image with wavelet transform at first, then we decompose high-frequency sub-images with Haar transform. The nonlinear soft threshold filtering method is used to remove noise, different enhancement weight coefficients in different sub-images are used to enhance an image, and the nonlinear histogram

equation is used to stretch the intensity range after a medical image's decomposition. The detailed process is as follows.
An image can be seen as a 2D signal, so an image's wavelet transform can be obtained by the Mallat algorithm[1]. In the wavelet frequency field, an image's edge feature information and detail information are distributed in high-frequency sub-images. When we decompose an image through wavelet transform of k scales, we can get 3k+1 sub-images:

$$\{\mathbf{LL}_k, \mathbf{HL}_j, \mathbf{LH}_j, \mathbf{HH}_j\} \tag{3}$$

wherej j=1, 2,... ,k,k denotes the image's decomposition scale levels of wavelet transform, $\mathbf{LL}_k$ denotes the kth scale level low-frequency sub-image, and $\mathbf{HL}_j, \mathbf{LH}_j, \mathbf{HH}_j$ denote the jth scale level high-frequency sub-images.

But there is still more detailed information in these sub-images. In order to obtain more image detail information, all high-frequency sub-images are decomposed with Haar transform. This method is simpler than the wavelet packet transform and the general multi-wavelet transform for that Haar transform is the simplest inverse symmetry orthogonal transform and is only used to decompose high-frequency sub-images. It can help us to obtain more detailed information in all level sub-images except low-frequency sub-images here. Also, it is used here to help us to obtain four new sub-images of every high-frequency sub-image of wavelet transform, and they are:

$$\begin{gathered}\{\mathbf{HL}_{j00}, \mathbf{HL}_{j01}, \mathbf{HL}_{j10}, \mathbf{HL}_{j11}\}\\ \{\mathbf{LH}_{j00}, \mathbf{LH}_{j01}, \mathbf{LH}_{j10}, \mathbf{LH}_{j11}\}\\ \{\mathbf{HH}_{j00}, \mathbf{HH}_{j01}, \mathbf{HH}_{j10}, \mathbf{HH}_{j11}\}\end{gathered} \tag{4}$$

wherej¼1, 2,... , k, j00,j01,j10 andj11 denote the position of four sub-images that have been derived from Haar transform. Fig. 1 is the high-frequency sub-image's Haar transform

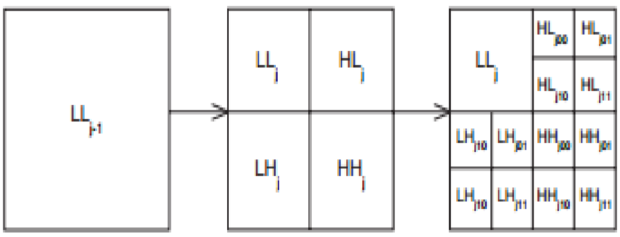

Fig. 1:Image wavelet decomposition and Haar transform of high-frequency sub-images

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 give space localization information for a certain image pat- tern (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 WT gives both the frequency

There is an abundance of image detail information in high-frequency sub-images.

B. Soft Threshold Method

But there are also plenty of noise in these sub-images. The wavelet transform's smooth function can help us to reduce an image's noise, but it cannot meet our requirements. Haar transform can also help us to reduce some noise, but still there is much noise in high frequency sub-images. If we enhance high-frequency coefficients at this time, image detail information and noise are all enhanced. We reduce noises of high-frequency sub-images through the nonlinear method. Because the noise properties are different in different high frequency sub-images, different soft thresholds are used to reduce noise in different sub-images. To set the soft threshold

$$T_{jil} = \sigma_{jil}\sqrt{2\log N_{jil}}$$

where

$$\sigma_{jil} = \sqrt{\frac{1}{N_{jil}}\sum_{k=1}^{N_{jil}}(x_{jil}^k - \bar{x}_{jil})^2} \tag{5}$$

J denotes scale levels,,i (j=1, 2, 3) denote HL,LH,HH high-frequency sub-bands, respectively, and l (l = 00, 01, 10, 11) denote Haar transform sub-images of high-frequency i. N_{jil} represents signal length, x_{jil}^k are coefficients, and $\bar{x}_{jil}$ denotes the mean value of the jil sub-image. The formula of reducing noise is

$$G(x,y) = \begin{cases} H(x,y) - T_{jil}, & H(x,y) \geq T_{jil} \\ 0, & -T_{jil} \leq H(x,y) \leq T_{jil} \\ H(x,y) + T_{jil}, & H(x,y) \leq -T_{jil} \end{cases} \tag{6}$$

where T_{jil} are soft threshold values of the jil sub-image, values of j, i, l are represented in the preceding equation, H(x, y) denotes the high-frequency coefficient of the position (x, y) in the jil sub-image, and G(x, y) denotes the coefficient of the position (x, y) denoised.

After the soft-threshold filter, we enhance high-frequency sub-images by enhancement weight coefficients. Different high-frequency sub-images denote different detailed information of an image, So we should enhance different sub-images through different enhancement weight values. Let set weight coefficients be W_{jil}, then we enhance all the high-frequency sub-image coefficients with the following formula

$$M(G(x,y), W_{jil}) = W_{jil}G(x,y) \tag{7}$$

Where G(x, y) denotes denoised high-frequency coefficients of the ijl sub-image in formula (5) and M(G(x, y), W_{jil},) denote enhanced coefficients.

Through the inverse wavelet transform and the inverse Haar transform, the enhanced image was generated. But the pixel grayscale range of the enhanced image is narrower than a normal image. Also it makes an image look unclear. Nonlinear histogram equalisation is used to stretch the greyscale range:

$$T(f(x,y)) = \begin{cases} f(x,y)M/N, & f(x,y) \in [0, N] \\ \dfrac{(f(x,y)-N)(255-2M)}{(f_{\max}-2N)} + M, & f(x,y) \in (N, f_{\max}-N] \\ (f(x,y)-f_{\max}+N) M/N + 255 - M, & f(x,y) \in (f_{\max}-N, f_{\max}] \end{cases} \quad (8)$$

Where f(x, y) denotes an image's pixel of position (x, y), T(f(x, y)) denotes the corresponding transformed pixel ,$f_{\max}$ is the maximum intensity of the image, M[(0, 255],N[(0,$f_{\max}$]. Formula (8) is a nonlinear method, and we can use it to obtain the image's new intensity range by changing parameters M and N according to the actual requirements

III. IMAGE CONTOUR ENHANCEMENT

An adequate operation by weighing the WT coefficients followed by inversing the WT results in the enhancement of image edges. Therefore the selection of weighting values for the WT coefficients is of importance. Figure 2 shows the flow chart of the image enhancement using the WT

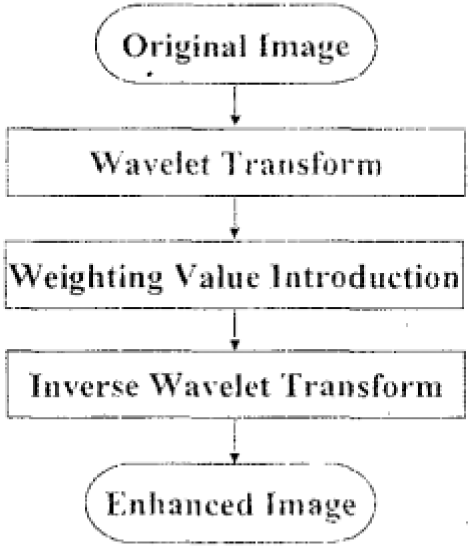

Fig.2: Flow chart of image enhancement using the wavelet transform .

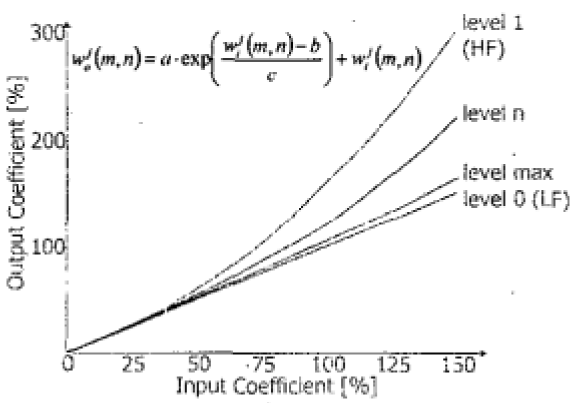

Fig.3:Coefficients transfer curves

In the present paper we propose a nonlinear transfer function curve for image enhancement. The transfer function curve is used to manipulate WT coefficients at various levels with different weighting values. The transfer function was determined based on the following considerations: (I) in the case of detail components $ at a specific level, the coefficients having great value are aggressively weighted, since they can more effective information, (2) the coefficients at low levels are aggressively weighted, since they cany edge information and (3) the scaling coefficient of level mar is not manipulated for preventing image distortion. The coefficient w'(m,n) of level j at position (m,n) is manipulated using Eq. (9).

$$w_0^j(m,n) = a \cdot \exp\left(\frac{w_i^j(m,n)-b}{c}\right) + w_i^j(m,n) \quad (9)$$

where w(!(m,n) is the coefficient after weighting manipulation. a, b. and c are the constants determined depending on the extent of enhancement. In practice, Eq. (9) is used instead of Eq. (10)

$$w_0^j = a \cdot \exp\left(\frac{w_i^j - b}{c}\right) + w_i^j \quad [\%] \quad (10)$$

where wi and wj are input and output coefficients, respectively. The two values are expressed by percentage for the ease of computation. In the present study the constant a shown in Eqs. (9) and (10) are computed using Eq. (11). The values of the Constants b and c used are 25 and 24.94

$$a = (\max - \text{level} + 1)/\max \quad (11)$$

IV CONCLUSION

An important problem of medical image enhancement based on wavelet transform is how to extract high-frequency information. Haar transform is used to decompose the high-frequency sub-images of wavelets in this Letter. This helps us to extract high-frequency information effectively. Different enhancement weight coefficients in different sub-images and nonlinear histogram equalisation are used in the process of medical image enhancement. They can also help us to enhance a medical image effectively. Results of experiments show that the algorithm not only can enhance an image's contrast, but also can preserve the original image's edge property effectively. We use two level wavelet transform to decompose an image in this paper. The level of wavelet decomposition is preferably not more than four times for reasons of soft threshold filtering, else it may reduce the quality of detailed information.

we proposed a method for image enhancement. The method was to apply a nonlinear transfer function to wavelet coefficients and then reconstructing an enhanced image with the weighted coefficients. Our preliminary results show that the proposed method is effective and superior to the FFT method in image enhancement.

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