Medical Image Edge Detection using MRA based Wavelet Transforms

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Abstract—In this paper, Edge of the image can be detected by using various orthogonal and Biorthogonal wavelets based on MultiResolution Analysis. Biorthogonal wavelet provides symmetry of the coefficients than orthogonal wavelets. The properties of the biorthogonal are symmetry and vanishing moments which can be selected in the construction of edge detection. MultiResolution Analysis (MRA) method is proposed with the help of thresholding technique. The image is decomposed in first level, we have to take horizontal, vertical and diagonal details in order to find the edge points, the edge detected image can be reconstructed by applying inverse discrete wavelet transform.

Keywords— BIORTHOGONAL WAVELET; MULTI RESOLUTION ANALYSIS; EDGE DETECTION

I. INTRODUCTION

Edge is the most important information of image. The Edges of the images have always been used as primitives in the field of image analysis, segmentation and object tracing. Using wavelet transform to detect image edge is popular method. Depending upon the properties of the wavelet, the quality of the edge results would be obtained[8]. Wavelet transform is a representation of a signal in terms of a set of basis functions which are obtained by dilation and translation of a basic wavelet. It has found applications in edge detection. Wavelet based edge detection avoids the intrinsic redundancy which appears in the approaches where a Gaussian filtering is used. Differing from infinite support of a Gaussian function, a wavelet is localized in both time and frequency domains, which can bring a more accurate result in edge detection.

An important property of human visual system is that people are more tolerant of symmetric errors than asymmetric ones. Therefore, it is desirable that the wavelet and scaling functions are symmetric. Unfortunately, it has been shown that the properties of orthogonality and symmetry conflict each other in the design of compactly supported wavelet. Owing to this analysis we use symmetric biorthogonal wavelets in our research [10].In terms of wavelets with Multi Resolution Analysis method is proposed. With this method we are finding the edges with use of various orthogonal and Biorthogonal wavelet family.

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II. ORTHOGONAL WAVELETS

The wavelet transform is based on time frequency analysis and it provides flexible window size. The wavelet transform is characterised by two functions i.e scaling function and wavelet function. These functions are like twin function. The wavelet functions are derived from the scaling function. The scaling function is orthogonal to wavelet function and hence they are called orthogonal wavelets. The support interval of wavelet is the range of the interval over which the scaling and wavelet function is defined. These are finite support and compact wavelets which are more popular due to their relations to multiresolution filter banks. Orthogonal wavelet systems decompose signals into well-behaved orthogonal signal spaces. However, the analysis and synthesis filters are not symmetric .There are different types of orthogonal wavelets such as Haar, daubechies, symlets, coiflets, etc. These are compactly supported orthogonal wavelets thus making discrete wavelet analysis practicable.

III. BIORTHOGONAL WAVELETS

The design of orthonormal wavelets requires a step known as spectral factorization, which can make the filter lengths grow when going to coarser scales; moreover, orthogonal filters cannot be symmetric. These limitations are also encountered in classical wavelet filter design, and they can be circumvented by relaxing the orthogonality condition and considering biorthogonal wavelet.

Daubechies said that the only symmetric, finite length, orthogonal filter is the haar filter [6]. While talking about the limitations of the haar wavelet, the shorter filter length sometimes fails to detect large changes in the input data. So we are interested to design symmetric filters of length greater than 2. The goal is to construct two low pass filters h and $\widetilde{h}$ and their associated high pass filters g and $\widetilde{g}$.

A. Scaling and Wavelet functions

Let $(h_n)_{n\in Z}$ and $(\widetilde{h}_n)_{n\in Z}$ be the finite real sequences, the associated scaling functions ϕ and $\widetilde{\phi}$ are recursively defined as

$$\phi(x)=\sqrt{2}\sum_n h(n)\phi(2x-n),$$

$$\text{and} \qquad \widetilde{\phi}(x)=\sqrt{2}\sum_n \widetilde{h}(n)\widetilde{\phi}(2x-n) \qquad (1)$$

The associated wavelets ψ and $\widetilde{\psi}$ are defined as,

$$\psi(x)=\sqrt{2}\sum_n g_{n+1}\phi(2x-n),$$

$$\text{and} \qquad \widetilde{\psi}(x)=\sqrt{2}\sum_n \widetilde{g}_{n+1}\widetilde{\phi}(2x-n) \qquad (2)$$

Where $g_{n+1}=(-1)^n\widetilde{h}(1-n)$, and $\widetilde{g}_{n+1}=(-1)^n h(1-n)$.

Such a set of four functions $\{\phi,\widetilde{\phi},\psi,\widetilde{\psi}\}$ forms a two band biorthogonal wavelet system [10].

B. Symmetric filters

It is possible to construct smooth biorthogonal wavelets of compact support that are either symmetric or antisymmetric. This is impossible for orthogonal wavelets, besides particular case of the Haar basis. Symmetric or antisymmetric wavelets are synthesized with perfect reconstruction filters having a linear phase.

Consider all filters are finite length. If the filter length is odd, we require our filter to be symmetric about zero and when the filter length is even, filter be symmetric about ½ [4].

Let h=$(h_l......h_L)$ be a finite length filter with length N=L-l+1. We say that h is symmetric if

(a) $h_k=h_{-k}$ for all k ∈ Z whenever N is odd.

(b) $h_k=h_{1-k}$ for all k ∈ Z whenever N is even.

Symmetric filters are good for minimizing the edge effects in the representation of the discrete wavelet transform (DWT) of a function[2].Larger coefficients results the false edges due to periodization is avoided.

C. Orthogonality in the Fourier Domain

The Orthogonality conditions that the filter pairs h and $\widetilde{h}$, g and $\widetilde{g}$ must satisfy

$$\widetilde{H}(\omega)\overline{H(\omega)}+\widetilde{H}(\omega+\pi)\overline{H(\omega+\pi)}=2 \qquad (3)$$

If $H(\omega)$ and $\widetilde{H}(\omega)$ satisfy, then we have

$$\sum_{k\in Z}\widetilde{h}_k h_k=1 \qquad (4)$$

and for $m\in Z, m\neq 0$,

$$\sum_{k\in Z}\widetilde{h}_k h_{k-2m}=0 \qquad (5)$$

IV. MULTIRESOLUTION ANALYSIS

Wavelet transforms and other discrete multiresolution techniques enjoy a rich interpretation in terms underlying continuous basis functions. These functions form bases for specifically structured subspaces known as a multiresolution analysis (MRA) [1]. A biorthogonal MRA is defined as two subspaces.

$$\ldots \subset V_2 \subset V_1 \subset V_0 \subset V_{-1} \subset V_{-2} \subset \ldots$$

$$\ldots \subset \widetilde{V}_2 \subset \widetilde{V}_1 \subset \widetilde{V}_0 \subset \widetilde{V}_{-1} \subset \widetilde{V}_{-2} \subset \ldots$$

which satisfy the following properties.

Completeness:

$$\bigcup_{j\in Z} V_j = \bigcup_{j\in Z} \widetilde{V}_j = L^2(R) \qquad (6)$$

Intersection:

$$\bigcap_{j\in Z} V_j = \bigcap_{j\in Z} \widetilde{V}_j = \{0\} \qquad (7)$$

Scale invariance:

$$f(x) \in V_0 \Leftrightarrow f(2^j x) \in V_j \qquad (8)$$

Shift invariance:

$$f(x) \in V_0 \Rightarrow f(x-k) \in V_0 \qquad \forall k \in Z \quad (9)$$

Biorthogonal basis:

$$\exists \phi, \widetilde{\phi} \text{ such that span } \{\phi(x-k)\} = V_0$$

$$\text{span } \{\widetilde{\phi}(x-k)\} = V_0$$

and

$$\langle \phi(x-m), \widetilde{\phi}(x-n) \rangle = \delta_{mn} \qquad \forall k, m, n \in Z \quad (10)$$

Whenever these properties are satisfied, the MRA is existed the biorthogonal wavelet functions ψ and $\widetilde{\psi}$ $\langle \psi_m, \widetilde{\psi}_n \rangle = \delta_{mn}$, $\langle \phi_m, \widetilde{\psi}_n \rangle = \langle \widetilde{\phi}_m, \psi_n \rangle = 0, \ \forall m, n \in Z$.

V. ANALYSIS METHOD

The Proposed Method is Edge detection using biorthogonal wavelet associated with Multi Resolution Analysis (MRA) method. MRA is to provide "Views" the image in different scales[7]. The block diagram shows the procedure to find out the edges for image.

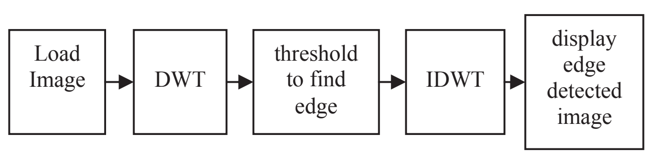


Fig.1.Block diagram of edge detection method

Edge detection is very useful application in medical image processing for analyzing the patient health records. In this paper we are taken medical image of ribs of one sided is to find out the edges of the ribs. The following steps are to find out the algorithm that is given below.

1) Load the image of ribs and read all the coefficients.
2) Apply the Discrete Wavelet Transform in order to decompose the wavelet in first level is to provide horizontal, vertical and diagonal details.
3) For a bounded region of MRA threshold can be calculated and find out the number of edge points.
4) Apply the Inverse Discrete Wavelet Transform to reconstruct the image.
5) Display the edge detected image for different biorthogonal and orthogonal wavelets.
6) Calculate the Computation time, number of edge points and Peak Signal to Noise Ratio (PSNR).

In this method the selection of the range of low and high frequency is difficult in order to obtaining the all the edge details[3]. If the range is too large then some of the details is deleted. In opposition, if the range is too small, and a lot of additional points may be preserved and the real edge information may be covered [9].

A. Peak Signal to Noise Ratio

For the purpose of testing the performance of reconstructed edge image, The Mean Square Error (MSE) can be defined as

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left\| I(i,j) - K(i,j) \right\|^{2} \quad (11)$$

where j and i are total number of pixels of in the horizontal and vertical dimensions of the image; $I(i,j)$ is the

Original image and $K(i,j)$ is edge detected image with M X N pixels.

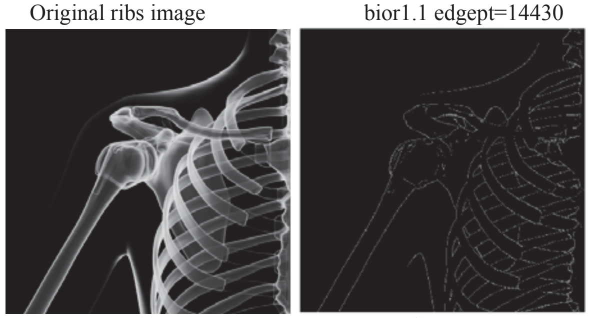
$$PSNR = 20\log_{10}\left(\frac{255}{\sqrt{MSE}}\right) \quad (12)$$

The Original image dimensions are 394x394. We calculated PSNR for every wavelet and tabulated in Table1 and Table2.

VI. Results and Discussions

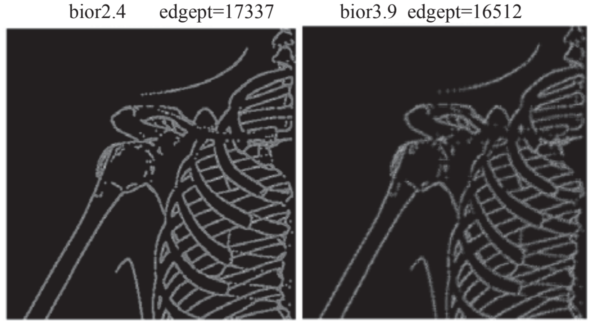
In order to test edge detection performance of biorthogonal wavelet, we use test image as ribs image shown in Fig.2(a).
The Program can be done in Matlab [5] and results of edge detection is shown in below.

Original ribs image bior1.1 edgept=14430



(a) (b)

bior2.4 edgept=17337 bior3.9 edgept=16512



(c) (d)

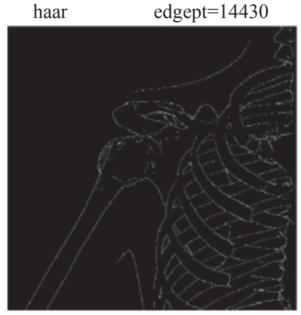
bior5.5 edgept=16464 bior6.8 edgept=18822

(e) (f)

Fig.2.(a) Original ribs one sided image and different Biorthogonal wavelets of edge detected images
(b)bior1.1 (c)bior2.4 (d)bior3.9 (e)bior5.5 (f)bior6.8

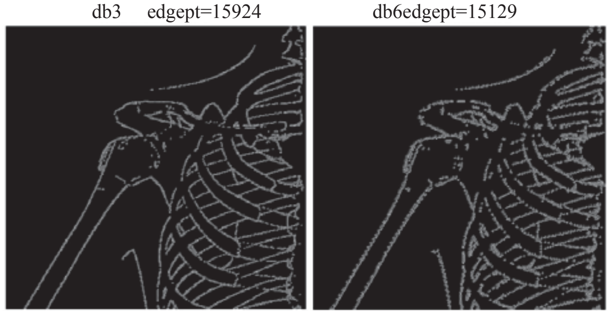
Edge detection is done using Multiresolution analysis of biorthogonal wavlets is shown in Fig2.Edge detected orthogonal wavelets like daubecheis, haar, symlet and coiflet with edgept repersents the edge points obtained from the image is shown in Fig.3.

haar edgept=14430



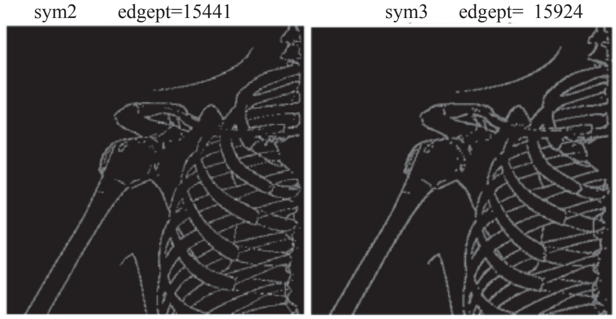
(a)

db3 edgept=15924 db6edgept=15129



(b) (c)

sym2 edgept=15441 sym3 edgept= 15924



(d) (e)

coif1 edgept=17070 coif2 edgept=17154

(f) (g)

Fig 3.Edge detected images of Orthogonal wavelets (a)haar (b)db3 (c)db6 (d)sym2 (e)sym3 (f)coif1 (g)coif2

Table 1
Comparisions of various Biorthogonal Wavelets for edge detection

wavelet type	bior1.1	bior2.4	bior3.9	bior5.5	bior6.8
computation time(sec)	2.1406	2.3438	2.4375	2.1719	2.4219
PSNR(dB)	12.8630	12.8626	12.8621	12.8631	12.8628
edgepoints	14430	17337	16512	16464	18822

Table 2
Comparision of various Orthogonal Wavelets for edge detection

Wavelet type	haar	db3	db6	sym2	sym3	coif1	coif2
computation time(Sec)	2.4063	2.7676	2.7031	2.2031	2.9063	2.2344	3.2031
PSNR(dB)	12.8630	12.8631	128630	12.8630	12.8631	12.8629	12.8630
edgepoints	14430	15924	15129	15441	15924	17070	17154

Computation time and PSNR is calculated for every wavelet shown in Table1.By analyzing the Fig.1,the main difference reflects at three aspects between varied wavelets.

Visual effects: From the Fig.2,it is clear that the resluts of ‘bior2.4’, ‘bior5.5’, ‘bior6.8’ are better than another bior family. The main features of original image can be extracted perfectly. Comparing to orthogonal wavelets bior5.5 is visually better than coif1,sym2,haar,db3.

Detection efficiency: From the Fig.2 and Fig.3 the detected edgepoints are shown in each image. The maximum one is ‘bior6.8’ wavelet. The detected edge points are 18822, but the image result is worst in all edge wavelet results. On the contrary, the minimum is ‘bior1.1’ and ‘haar’ wavelet with only 14430 edge points, but the edge detected image quality is less in visual comparision. The best detection efficiency is ‘bior1.1’ wavelet.

*Computation time and PSNR:*Less computation time is obtained for ‘bior1.1’ but best PSNR is obtained for ‘bior5.5’ in biorthogonal family.Comparing to orthogonal wavlets ‘db3’ got good PSNR but highest computation time is required.

VII. CONCLUSIONS

This paper proposes a Multi Resolution analysis using Biorthogonal wavelet. In process of analysis of Edge detection, we compared biorthogonal wavelets with orthogonal wavelets in terms of computation time, PSNR, and edge points. From the view of various points, we conclude that biorthogonal wavelets are better than orthogonal wavelets. Out of all the wavelet families bior5.5 edge detected image gives best edge detected image with less computation time and visibly good. The analysis is observed various Biorthogonal and Orthogonal family and results are included.

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