Performance Analysis of orthogonal and Biorthogonal wavelets for Edge detection of X-ray Images

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Abstract

The X-ray images are extensively used by the medical practitioners to detect the minute fractures of bone images as they are painless and economical compared to other image modalities. The minute fractures cannot be identified with naked eye. So the X-ray images are to be processed for detecting the minute fractures. The orthogonal wavelet transforms like Haar, daubechies etc can be used as edge detector, but a lot of false edge information will be extracted. Edge detection of X-ray images using Multiresolution Analysis(MRA) based biorthogonal wavelets is more preferable when compared with orthogonal wavelets because of more flexibility.. Therefore biorthogonal wavelet transforms like bior1.3, bior2.4 are applied to detect the edges and are compared for edge feature extraction. Among all the methods, biorthogonal wavelet bior1.3 performs well in detecting the edges with better quality. The various performance metrics like Ratio of Edge pixels to size of image (REPS), peak signal to noise ratio (PSNR) and computation time are compared for various wavelets for edge detection.

keywords: Edge detection; Multi-resolution analysis; orthogonal wavelet; biorthogonal Wavelet transform

1. INTRODUCTION

Edge detection of X-ray images delivers details about fracture in bone and plays an important role in patient diagnosis for doctors. Bone edge detection in medical images is a crucial step in image guided surgery. Edge feature extraction of X-ray bone image is very useful for the medical practitioners as it provides important information for diagnosis which in turn enable them to give better treatment decisions to the patients. Presently digital images are increasingly used by medical practitioners for disease diagnosis The images are produced by several medical equipments like MRI, CT, ultrasound and X-ray. Out of these, X-ray is the oldest and frequently used devices, as they are painless and economical. The X-ray images are used during various stages of treatment which include fracture diagnosis and treatment. Edge feature extraction deals with extracting or detecting the edge of an image. It is the most common approach for detecting meaningful discontinuities in the gray level [11]. It is one of basal

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contents in the image processing and analysis, and also is a kind of issues which are unable to be resolved completely so far [3]. When image is acquired, the factors such as projection, mix, and noise are produced. These factors bring on image feature’s blur and distortion, consequently it is very difficult to extract image feature. Moreover, due to such factors it is also difficult to detect edge [9].

The classical derivative operators such as Roberts, Prewitt, sobel, Laplacian of Gaussian[4][6] can be used. But a lot of false edge information will be extracted. They are also sensitive to noise. These operators are applied on pixel by pixel basis. They are slow in operation. The high frequency components of an image includes both edges and noise. So detecting the edge is not an easy task. Therefore an efficient technique based on wavelet transform is used to detect the edges. This is because wavelet transform has the advantage of detecting edges using different scales. The orthogonal wavelet transforms like Haar, daubechies, symlets can be used to detect the edges of an image. But a lot of false edge information will be extracted. They are also sensitive to noise. Depending upon the properties of the wavelet, the quality of the edge results would be obtained [8]. As there are different properties of the wavelet such as orthogonality, symmetry and vanishing moments which can be varied, therefore qualities of detected edge are different. The biorthogonal wavelet is more advantages compared to orthogonal wavelet. 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, the properties of orthogonality and symmetry conflict each other in the design of compactly supported wavelet. Owing to this analysis it is necessary to use symmetric biorthogonal wavelets [10].

2. Wavelet Transform Theory

Frequency domain analysis using fourier transform is extremely useful for analysing the signal because the signal’s frequency content is very important for understanding the nature of signal and the noise that contaminates it. The only drawback is, loss of time information. When looking at a fourier transform of signal, it is impossible to tell when a particular event took place. So to overcome this drawback, the same transform was adapted to analyse only a small window of the signal at a time. This technique is known as short time fourier transform which maps a signal into a two dimensional function of time and frequency to get the localized point information but the only drawback is that, the window size is same for all frequencies. Many signals require more flexible approach that is flexible window size. This technique is known as wavelet transform. A wavelet is a “small wave”, which has its energy concentrated in time to give a tool for the analysis of transient, non-stationary, or time-varying phenomena about analyzing signal with short duration finite energy functions [1]. They transform the signal under investigation into another representation which presents the signal in a more useful form. It still has the oscillating wave-like characteristic but also has the ability to allow simultaneous time and frequency analysis with a flexible mathematical foundation. Wavelet transform is widely used in image processing. Wavelet transform of a signal means to describe the signal with a family of functions. In two-dimensional images, the intensity of edges can be enhanced in each one-dimensional image. If the window of the images is convolved in the x direction over an image, a peak will result at positions where an edge is aligned with the y direction. This operation is approximately like taking the first derivative of the image intensity function with respect to x or y.

2.1. Orthogonal Wavelets

The discrete wavelet transform have two functions i.e scaling function and wavelet 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 [8]. There are different types of orthogonal wavelets such as Haar, daubechies, coiflets, etc. These are compactly supported orthogonal wavelets thus making discrete wavelet analysis practicable.
2.2 Biorthogonal Wavelet Theory

The wavelet expansion system is to be orthogonal across both translations and scale which gives a clean, robust, and symmetric formulation with Parseval’s theorem. It also places strong limitations on the possibilities of the system. The orthogonality has large number of the degree of freedom. It results in complicated design equations, prevents linear phase analysis and synthesis filter banks, and prevents asymmetric analysis. This develops the biorthogonal wavelet system using a nonorthogonal basis and dual basis to allow greater flexibility in achieving other goals at the expense of the energy partitioning property. Some researchers have considered “almost orthogonal” systems where there is some relaxation of the orthogonal constraints in order to improve other characteristics [10]. The design of orthonormal wavelets requires a step known as spectral factorization, which can make the filter lengths grow. 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 it necessary to design symmetric filters of length greater than two [9]. 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 filters are good for minimizing the edge effects in the representation of the discrete wavelet transform (DWT) of a function [2]. Larger coefficients results in the false edges as the periodization is avoided.

3. Wavelet Multiresolution Analysis

When an image is decomposed into finer and finer details, the multiresolution formulation can be used to represent the image. Multiresolution analysis allows decomposition of signal into various resolution levels. The practical interpretations of wavelets seem to be best served by using the concept of resolution to define the effects of changing scale. In one level decomposition level, the image will be divided into four sub bands, called LL, LH, HL, and HH [13]. The LL sub band is a low-resolution residue that has low frequency components, which are often referred to as the average image. LH provides horizontal detailed images. HL provides vertical detailed images. The HH sub band image gives diagonal details. 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].

4. Edge Detection

Edge detection is very important in the digital image processing, because the edge is boundary of the target and the background. The target and the background can be differentiated from the edges. But the borderline detected may produce interruption as a result of existing noise and image dark.

4.1 procedure for wavelet based edge detection
(1) Consider the image for which, the edge is to be detected. Apply the various types of wavelet transforms like Haar, dehauchies, symlets, bior 1.3, bior2.4 to the image.
(2) This wavelet transform split the image into low frequency, horizontal, vertical and diagonal components.
(3) Now add all the horizontal, vertical and diagonal components. Make a threshold based on wavelet coefficients summation values and the threshold value is half of the maximum value in the summation values.
(4) Make all the coefficients to one which are greater than the threshold and suppress the remaining Coefficients to zero in the summation values.
(5) Now apply the inverse discrete wavelet transform to the summation Coefficients.
(6) Now an image with only edges can be detected.

4.2 Performance metrics
(i) Visual effects: The quality of an image is subjective and relative, depending on the observation of the user.
(ii) **Ratio of edge pixels to size of image (REPS):** If the pixel value of image is greater than the threshold value, then it is considered as edge pixel or edge point [7]

\[ \text{REPS(\%)} = \frac{\text{No. of Edge Pixels}}{\text{Size of an image}} \times 100 \quad (1) \]

(iii) **Peak Signal to Noise Ratio (PSNR):** It is one of the parameters that can be used to quantify image quality. A larger PSNR produces better image quality.

\[ \text{PSNR} = 20 \log_{10} \frac{255}{\sqrt{\text{MSE}}} \quad (2) \]

where mean square error [12]

\[ \text{MSE} = \frac{1}{mn} \sum_{x=1}^{m} \sum_{y=1}^{n} (I(x,y) - I'(x,y))^2 \quad (3) \]

\(I(x,y)\) is Original Image, \(I'(x,y)\) is edge detected image

(iv) **Computation time:** It is the time taken to execute the Program

5. **Results and Discussion**

In this paper, right hand X-ray bone image with minute fracture at the neck of the fourth metacarpal bone and fractured foot image are considered. In order to calculate the edge features of this image, a new algorithm is implemented using MATLAB 7.9. The various orthogonal wavelet transforms are applied to detect the edges of bone in X-ray hand and foot image. Fig. 2 and Fig. 3 shows the images processed by these methods.

Fig 2. (a) original X-ray hand image (b) haar wavelet edge detected image (c) db3 wavelet edge detected image (d) sym2 wavelet edge detected image (e) bior1.3 wavelet edge detected image (f) bior2.4 wavelet edge detected image

Fig 2. (a) original X Ray hand image (599x395) jpg (b)to(f) wavelet edge detected images
From the Fig.2 and Fig.3, it is clear that the results of bior 1.3 biorthogonal wavelet is superior than other wavelets for both hand image and foot image in terms of visual perception. The detected edge points are shown in Table.1 and Table.2. The number of edge points and REPS is less for bior1.3 wavelet when compared to other wavelets but visual perception is good for bior1.3 wavelet. Though the number of edge points and REPS is high for the other biorthogonal wavelets compared to bior1.3 wavelet, but their visual quality is less due to false edge points. The PSNR for bior1.3 wavelet is almost similar to other biorthogonal for both hand and foot image. The computation time is less for the bior1.3 wavelet transform when compared with other biorthogonal wavelets which are shown in the Table.2 and Table.3. In this paper, the threshold is set as 0.09-0.1 as it produces more edge points. The bior1.3 wavelet is the best due to its visual quality, less computation time when compared with other wavelets.
Table 2. Performance metrics for edge detected X-ray foot image

<table>
<thead>
<tr>
<th>Wavelet type</th>
<th>Haar</th>
<th>db3</th>
<th>Sym2</th>
<th>bior1.3</th>
<th>bior2.4</th>
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<tr>
<td>Edge points</td>
<td>218725</td>
<td>222065</td>
<td>224690</td>
<td>222964</td>
<td>229276</td>
</tr>
<tr>
<td>PSNR(dB)</td>
<td>7.3288</td>
<td>7.3287</td>
<td>7.3287</td>
<td>7.3287</td>
<td>7.3281</td>
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<tr>
<td>Computation time</td>
<td>11.4063</td>
<td>17.3287</td>
<td>18.2969</td>
<td>16.5469</td>
<td>16.6719</td>
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<tr>
<td>REPS</td>
<td>6.95</td>
<td>7.06</td>
<td>6.96</td>
<td>7.087</td>
<td>7.28</td>
</tr>
</tbody>
</table>

6. Conclusions

In this paper, the performance of various orthogonal and biorthogonal wavelets based on Multiresolution analysis are compared for edge detection of X-ray images to identify the minute fractures. In the process of analysis of Edge detection, various wavelets are compared in terms of PSNR, Ratio of Edge pixels to size of image (REPS) and computation time. Among all the wavelets, the biorthogonal wavelet bior1.3 edge detected image gives best edge detected image having good quality of edge with less computation time. The PSNR value of edge detected hand image based on bior1.3 wavelet is 11.3718 dB and for foot image it is 7.3287 dB. The computation time of bior1.3 wavelet for hand image is 1.4688 sec and for foot image it is 16.5469 sec which is less when compared to the other wavelets. The bior1.3 wavelet gives best result when compared with other wavelets for detecting the edges to identify the minute fractures of an X-ray image. The multiresolution analysis of wavelet transform can improve the quality of edge detection. Since the threshold is selected directly from the coefficients of wavelet transform, the quality of edge detection of X-ray bone image is very good.

References