Medical Image Compression using Different Wavelet Families

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Abstract

The study presents the importance of image compression in medical images. There are different types of medical images that are used for diagnosed. So we need to store all the diagnostic images regarding the patient. This paper is focused on selecting the most appropriate wavelet function for biomedical images. In this paper we perform compression by using different type of wavelet function with different type of biomedical images and suggested the most appropriate wavelet function that can perform optimum compression for a given type of biomedical image. To analyze the performance of the wavelet function with the biomedical images we fixed the loss amount of the data in the compressed image (Quality of the compressed image will be same for each wavelet function) and calculated their respective compression ratio. The wavelet function that gives the maximum compression for a specific type of biomedical image will be the most appropriate wavelet for that type of biomedical image compression.

Keywords: Maximum error (MSE), peak signal to noise ratio, (PSNR), Threshold, wavelet transform and mean square error.

1. Introduction

Image compression is an application of data compression on digital images. Image compression is minimizing the size in bytes of a graphics file without degrading the quality of the image. The reduction in file size allows more images to be stored in a given amount of disk or memory space. It also reduces the time required for images to be sent over the Internet or downloaded from Web pages. Compression is useful because it helps to reduce the consumption of expensive resources, such as hard disk space or transmission bandwidth (computing) [2]. There are several different ways in which image files can be compressed.

In many Medical Applications, for fast interactivity while browsing through large sets of images (e.g. volumetric data sets, time sequences of images, image databases) or, for searching context dependent detailed image structures, and/or quantitative analysis of the measured data Compression is required. In medical imaging the loss of any information when storing or transmitting an image is unbearable [5] [13]. There is a broad range of medical image sources, and for most of them discarding small image details that might be an indication of pathology could alter a diagnosis, causing severe human and legal consequences. The increasing use of three dimensional imaging modalities, like Magnetic Resonance Imaging (MRI), Computerized Tomography (CT), and Ultrasound (US) triggers the need for efficient techniques to transport and store the related volumetric data.

In this work we will decide that which wavelet function is suitable for a given biomedical image. In our study we have taken six different types of biomedical images:-
1. X-Ray Image
2. MRI Image
3. Ultrasound Image
4. Mammography Image
5. CT Scan
6. Optical imaging

2. Wavelet Transform

Wavelet means a “small wave”. The smallness implies to a window function of finite length (compactly supported). Wavelets are functions that satisfy certain mathematical requirements and are used in representing data or other functions. A wavelet is a waveform of effectively limited duration that has an average value of zero. Wave in itself refers to the condition that this function is oscillatory. And Wavelet analysis has the ability to perform local analysis i.e. it can analyze a localized area of a larger signal. Wavelet analysis is capable of revealing aspects of data that other signal
analysis techniques miss aspects like trends, breakdown points, discontinuities in higher derivatives, and self-similarity [4, 7, and 15]. Wavelet compression involves a way analyzing an uncompressed image in a recursive fashion, resulting in a series of higher resolution images, each “adding to” the information content in lower resolution images. The primary steps in wavelet compression are performing a discrete wavelet Transformation (DWT), quantization of the wavelet-space image sub bands, and then encoding these sub bands. Wavelet images by and of themselves are not compressed images; rather it is quantization and encoding stages that do the image compression. Image decompression, or reconstruction, is achieved by carrying out the above steps in reverse order [5, 6]. Wavelets are generated from one single function (basis function) called the mother wavelet. Mother Wavelet is a prototype for generating the other window functions [7, 14]. The mother wavelet is scaled (or dilated) by a factor of ‘a’ and translated (or shifted) by a factor of ‘b’ to give (under Morlet's original formulation):

$$\psi_{a,b}(t) = \left(\frac{1}{\sqrt{a}}\right) \psi\left(\frac{t-b}{a}\right)$$

The following diagram shows wavelet based compression & decompression method [12].

There are many members in the wavelet family, a few of them that are generally found to be more useful, are as per the following Haar wavelet is one of the oldest and simplest wavelet. Therefore, any discussion of wavelets starts with the Haar wavelet. The wavelets are chosen based on their shape and their ability to analyze the signal in a particular application [9, 12].

A. Haar- This wavelet is discontinuous, and resembles a step function.

B. Coiflets- The wavelet function has 2N moments equal to 0 and the scaling function has 2N-1 moments equal to 0.

The two functions have a support of length 6N-1.

C. Symlets- The symlets are nearly symmetrical wavelets. The properties of the two wavelet families are similar

D. Meyer - The Meyer wavelet and scaling function are defined in the frequency domain.

E. Biorthogonal- This family of wavelets exhibits the property of linear phase, which is needed for signal and image reconstruction. By using two wavelets, one for decomposition (on the left side) and the other for reconstruction

(On the right side) instead of the same single one, interesting properties are derived.

F. Daubechies- Daubechies are compactly supported orthonormal wavelets and found application in DWT. Its family has got nine members in it [16].

3. Terminologies used in Image Compression

There are various types of terms that are used in calculation of image compression. Two mathematical terms are used in measuring the quality of the reconstructed image. One of them is MSE, which measures the mean square error between the original and the compressed image [10]. The other is the peak signal-to-reconstructed image measure known as PSNR. The formula for MSE is given as

$$MSE = \frac{1}{MN} \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} (I(i,j) - K(i,j))^2$$

The formula for PSNR is given as

$$PSNR = 10 \log_{10} \left( \frac{MAX_I^2}{MSE} \right) = 20 \log_{10} \left( \frac{MAX_I}{\sqrt{MSE}} \right)$$

4. Steps used in compression

The usual steps involved in compressing and decompressing of image are:

- a) Load original Image.
- b) Generate Compressed Image.
- c) Use Thresholding (‘wdencmp’) command for denoising the image.
- d) Calculate compression ratio for given image.
- e) PSNR is fixed in this compression method.
- f) Obtained reconstructed image.

We perform these steps for compression by using different type of wavelet function with different type of biomedical images and suggested the most appropriate wavelet function that can perform optimum compression for a given type of biomedical image.

5. Results and Discussions

For the above mentioned Wavelet methods, image compression is performed using wavelets and calculates the compression ratio with different wavelet families. Results of compression ratio for different wavelet families are shown in Table. To analyze the performance of the wavelet function with the biomedical images we fixed the loss amount of the data in the compressed image (Quality of the compressed image will be same for each
wavelet function) and calculated their respective compression ratio. The wavelet function that gives the maximum compression for a specific type of biomedical image will be the most appropriate wavelet for that type of biomedical image compression. The compression is executed in two steps first we perform first level of image decomposition and the second level of image decomposition takes place. After second level of decomposition we reconstruct the compressed image and calculate the threshold of the compression and PSNR. The threshold and PSNR are set in a way that their values will always be a constant for a given type of image compression. We keep on repeating this compression for different type of wavelet functions and calculate the compression ratio that can be achieved with each of them. Below is the output of the each type of image compression with different type of wavelet functions.

Table 5.1 Compression ratio for biomedical images with different type of wavelet families.

<table>
<thead>
<tr>
<th>Image Type</th>
<th>Harr</th>
<th>Coiflets</th>
<th>Biorthogonal</th>
<th>Daubechies</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-Ray</td>
<td>61.98</td>
<td>66.96</td>
<td>67.9446</td>
<td>60.9544</td>
<td>Biorthogonal</td>
</tr>
<tr>
<td>CT Scan</td>
<td>59.86</td>
<td>71.24</td>
<td>74.3577</td>
<td>69.7590</td>
<td>Biorthogonal</td>
</tr>
<tr>
<td>MRI Scan</td>
<td>67.90</td>
<td>75.06</td>
<td>76.4885</td>
<td>78.3455</td>
<td>Coiflets</td>
</tr>
<tr>
<td>Ultrasound</td>
<td>64.00</td>
<td>66.52</td>
<td>65.7688</td>
<td>64.7547</td>
<td>Daubechies</td>
</tr>
<tr>
<td>Mammography</td>
<td>59.86</td>
<td>73.28</td>
<td>72.7028</td>
<td>71.0167</td>
<td>Coiflets</td>
</tr>
<tr>
<td>Optical imaging</td>
<td>70.06</td>
<td>73.53</td>
<td>73.0190</td>
<td>71.8456</td>
<td>Daubechies</td>
</tr>
</tbody>
</table>

‘Coiflets’ gives better result in comparison to other Wavelet functions it provide compression ratio approximately 75.0670%. For Ultrasound Images ‘Daubechies’ provides the better result and its compression ratio is 64.7547%. For Mammography Images ‘Coiflets’ perform the most compression as it can provide compression ratio up to 73.2610% . This result is outcomes of the analysis for the different type of medical images.

Conclusion

We analyzed that the compression ratio obtained after each compression and decides which wavelet function can provide maximum compression ratio for a particular biomedical image. In our study we have applied different Wavelet functions on different type of biomedical images for a fix PSNR value and calculated the compression ratio.

After analysis we have found that, for X-Ray Images ‘Biorthogonal’ can provide the best result as its compression ratio is 67.9446%. For MRI Images ‘Biorthogonal’ can provide the best result as its compression ratio is 67.9446%. For Ultrasound Images ‘Coiflets’ perform the most compression as it can provide compression ratio up to 73.2610% . This result is outcomes of the analysis for the different type of medical images.

References