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Comparison of Wavelet Filters in Image Coding and Denoising using Embedded Zerotree Wavelet Algorithm

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Abstract: In this study, we present Embedded Zerotree Wavelet (EZW) algorithm to compress the image using different wavelet filters such as Biorthogonal, Coiflets, Daubechies, Symlets and Reverse Biorthogonal and to remove noise by setting appropriate threshold value while decoding. Compression methods are important in telemedicine applications by reducing number of bits per pixel to adequately represent the image. Data storage requirements are reduced and transmission efficiency is improved because of compressing the image. The EZW algorithm is an effective and computationally efficient technique in image coding. Obtaining the best image quality for a given bit rate and accomplishing this task in an embedded fashion are the two problems addressed by the EZW algorithm. A technique to decompose the image using wavelets has gained a great deal of popularity in recent years. Apart from very good compression performance, EZW algorithm has the property that the bitstream can be truncated at any point and still be decoded with a good quality image. All the standard wavelet filters are used and the results are compared with different thresholds in the encoding section. Bit rate versus PSNR simulation results are obtained for the image 256x256 barbara with different wavelet filters. It shows that the computational overhead involved with Daubechies wavelet filters but are produced better results. Like even missing details i.e., higher frequency components are picked by them which are missed by other family of wavelet filters.

Keywords: Embedded coding, image compression, subband coding, wavelet transform

INTRODUCTION

The basic idea of image compression is to try to reduce the average number of bits per pixel to adequately represent the image. Image compression is urgently needed for very large medical or satellite images, both for reducing the storage requirements and for improving transmission efficiency (Vellaiappan and Angam, 2012). Other main applications of image compression are multimedia databases, digital still cameras, printers and scanners etc. Since there is a growing demand for multimedia applications, an efficient scalable image and video compression techniques are mandatory.

A Progressive image transmission is supported by the embedded coding by the property of generating the bits in the bitstream in their relative order of importance. A given image coded at a certain bitrate in an embedded fashion stores all the lower rate codes at the beginning of the bit stream. Typically, before or when the target bit rate is met the encoding process can be stopped. Similarly, the decoder can interrupt decoding at any point in the bit stream and can construct any lower rate images (Adrain *et al*., 1999). For images, scalability is typically achieved by means of progressive transmission based on multi resolution coding. Many state-of-the-art multi resolution image coders are build based on the ideas introduced by Shapiro (2003). A multi resolution analysis is the design method of most of the practically relevant DWTs.

A 2-D Discrete Wavelet Transform (DWT) is applied to the image on a tile-by-tile basis for subband coding. For different directions and resolution levels, different wavelet filters are used for different directions and resolution levels. Although the convolutions in the discrete wavelet transform can still be computed efficiently on blocks of data, no partitioning of the image is required in wavelet coding. The advantage is that the typical blocking artifacts. Like the ones occurring in Joint Photographic Experts Group (JPEG), are avoided and the computing time is hardly increased. At low and intermediate compression ratios, better quality than JPEG can be obtained. At high compression ratios, the ringing artifacts are generally less than JPEG blocking artifacts.

Our main objective is to implement a complete EZW encoder by means of dominant pass and subordinate pass using various wavelet filters and to perform image denoising task by choosing appropriate threshold value.

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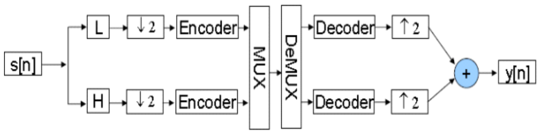
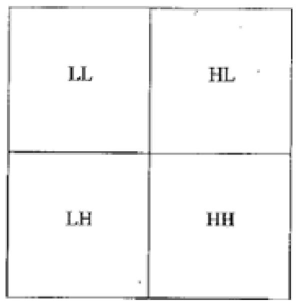
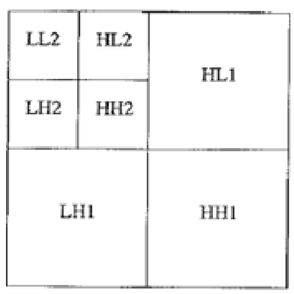


Fig. 1: Subband coding using QMF



(a)



(b)

Fig. 2: The two-dimensional DWT, (a) one-level transform, (b) two-level transform

METHODOLOGY SUBBAND CODING

A filter bank system of analysis and synthesis for Digital Signal Processing (DSP) has been developed by the principle of splitting a discrete time signal into a number of subband signals into final output signal. A two channel Quadrature Mirror Filter (QMF) can be used for the basic two channel subband coder/decoder (codec) as shown in Fig. 1.

A two-band analysis filter bank containing a low pass filter and high pass filter through which a input signal is passed. The subband signals are decimated (down sampled) by a factor 2. Since the range of frequencies at the output of the filter is less than the range of frequencies at the input to the filter, we can reduce the number of samples at the output of the filter (Khalid, 2000). Based on an energy level and perceptual importance, each decimated subband signal is encoded/quantized. Filtering and sub-sampling is termed as analysis stage. The decoded subbands are interpolated (up sampled) to achieve the reconstruction and appropriate synthesis filters are applied to produce the final output signal which is so called synthesis stage.

Table 1: Orthogonal wavelet filters

Wavelet	Number of taps	Cofficients
Haar	2	[0.707,0.707]
Daubechies 4	4	[0.483,0.837, 0.224,-0.129]
Daubechies 6	6	[0.332, 0.807.0.460-0.135,-0.085, 0.0352]
Daubechies 8	8	[0.230, 0715, 0.631.-0.028, -0.0187, 0.031, 0.033, -0.011]

The filters in a filter bank can be Finite Impulse Response (FIR) or Infinite Impulse Response (IIR) filters. FIR filters are generally used in most applications because of their design simplicity and better stability. Subbands formulation itself does not create any image compression. But the subbands can be encoded more efficiently than the source image. This process can be repeatedly used to obtain a larger number of bands. Some commonly used orthogonal filters are listed in Table 1.

The two-dimensional Discrete Wavelet Transform (DWT) can be applied to an image to the rows and columns. The procedure (Ze-Nian and Drew, 2004) for the two-dimensional DWT for an N by N input image is:

- Convolve each row of the image with analysis filters, remove the odd-numbered columns of the resulting arrays and concatenate them to form a transformed row
- Convolve each column of the result with analysis filters, again remove the odd-numbered rows and concatenate the result

Figure 2 shows that the one level and 2 level transform discrete wavelet transform to an image.

Embedded zerotree wavelet algorithm: The principle of operation of EZW (Zhen and Lina, 2000) is:

- Wavelet pyramid decomposition of the image
- Partial ordering of the transform coefficients by magnitude, with the ordering information encoded by means of a set of partitioning algorithm that is produced at the decoder
- Ordered bit plane transmission of refinement bits
- Exploitation of the self-similarity of the image wavelet pyramid decomposition across different scales. A pictorial representation of the zerotree on the three-stage wavelet decomposition is shown in Fig. 3a.

Example: A simple matrix of wavelet transform coefficients is considered here for an algorithm of EZW.

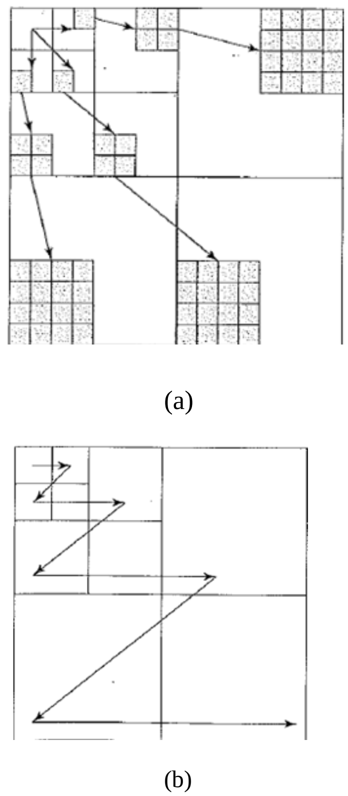


Fig. 3: (a) Parent-child relationship in a zerotree, (b) EZW scanning order

26	6	13	10
-7	7	6	4
4	-4	4	-3
2	-2	-2	0

Step 1: Find the maximum coefficient: 26
Step 2: Set initial threshold as To = $2(\log_2(26)) = 16$

- Since 26>16, assign sp (significant positive)
- Since 6<16 and 13, 10, 6, 4 all are less than 16, assign zr (zerotree root)
- Since -7<16 and 4, -4, 2, -2 all are less than 16, assign zr (zerotree root)
- Since 7<16 and 4, -3, 2, 0 all are less than 16, assign zr (zerotree root)

Step 3: The only significant coefficient in this pass, the one with value 26 which in included in the list to be refined in the subordinate pass.
Step 4: Reconstruct the coefficient: 1.5 T_0 = 24.
Step 5: Difference: 26-4 = 2.
Step 6: Threshold for the second level quantizer: $\pm T_0/4 = \pm 4$
Step 7: The new reconstructed value: 24+4 = 28.
Step 8: Set a new threshold by reducing the first one with factor of two i.e., 8 and repeat the process.

Features of EZW algorithm: At any time, the compression algorithm can be stopped and an approximate of the original image can be obtained at the decoder section. According to the incoming bit stream, the same algorithm can be run at the decoder to reconstruct the coefficients. It has the advantages of lower bandwidth, denoising and algorithm simplicity. A very good compression performance results are obtained with a technique that needs absolutely no training, no pre stored tables or code books and requires no prior knowledge of the image source.

Calculation of MSE and PSNR: MSE (Mean Square Error) and PSNR (Peak Signal-to-Noise Ratio) are the two performance metrics used to compare the image denoising techniques. MSE is defined by:

$$MSE = \frac{1}{N_1 N_2} \sum_{n_1=0}^{N_1-1} \sum_{n_1=0}^{N_2-1} (x[n_1,n_2] - x'[n_1,n_2])^2$$

where, $x[n_1, n_2]$ is the original image, $x'[n_1, n_2]$ is the reconstructed image and N_1 and N_2 are the dimensions of the image and the PSNR is defined by

$$PSNR = 10\log(\frac{(255)^2}{MSE})$$

SIMULATION RESULTS

Wavelet families can be classified into two main categories, orthogonal and biorthogonal wavelets. Each set have the different properties of basis functions. The redundancy can be minimized by the orthogonality which decorrelates the transform coefficients. The symmetry property achieves the linear phase and minimize border artifacts. A compact support, regularity, symmetry and degree of smoothness are the other important properties of wavelet functions.

We provide the results using both orthogonal and biorthogonal wavelet filters for the 256×256 barbara image using EZW algorithm by having the threshold value 25, 50 and 100 in the encoding section. Choosing a threshold value can help to reduce the noise content in the image thereby denoising is achieved. The simulation results are available in the Table 2 and 3 and Fig. 4 shows the original image, image after DWT, image after IDWT and the final reconstructed image after denoising.

Table 2: Bitrate versus PSNR for the image 'barbara'

Wavelet used	Bit Rate(bpp)	PSNR(dB)
Bior1.1	1.42	20.40
	0.50	20.40
	0.12	20.01
Bior4.4	120	20.21
	0.46	20.15
	0.12	19.88
Dmey	1.20	20.02
	0.47	19.95
	0.13	19.78
Coif1	1.34	20.20
	0.50	20.13
	0.13	19.70
Sym2	1.33	20.15
	0.49	20.06
	0.12	19.68

Table 3: Bitrate versus PSNR for the image 'barbara'

Wavelet used	Bit Rate(bpp)	PSNR(dB)
Daubechies 2	1.33	20.15
	0.49	20.06
	0.12	19.68
Daubechies 4	1.26	20.08
	0.49	20.06
	0.12	19.63
Daubechies 6	1.26	20.57
	0.48	20.57
	0.12	20.37
Daubechies 8	1.26	22.83
	0.48	22.82
	0.13	20.50
Daubechies 10	1.24	23.62
	0.47	23.55
	0.13	20.52

(a)

(b)

(c)

(d)

Fig. 4: (a) Original noisy image, (b) DWT, (c) IDWT, (d) final reconstructed image

CONCLUSION

Simulation Results show that 'db10' wavelet filter of Daubechies wavelet family obtain a better PSNR result at the cost of more computation. It is observed that the threshold value 50 would be optimal for better trade-off between bitrate and reconstructed image. T

The advantage of the Haar wavelet transform is very simple to compute and easy to understand. But the Daubechies transform is conceptually more difficult and complex and has a little higher computational overhead. But, the missing higher frequency components i.e., details by Haar wavelet are picked by Daubechies wavelet filters so that the better results are produced. An important property that the orthogonality which makes them energy preserving is useful for compression.

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