International Journal of Information & Computation Technology.
ISSN 0974-2255 Volume 1, Number 2 (2011), pp. 69-76

http://www.irphouse.com

Wavelet Based Image Compression Using ROI SPIHT Coding

A. Kumar Kombaiya[1] and V. Palanisamy[2]

Head, Department of Computer Applications SNR Sons College,
Coimbatore – 641006., Tamil Nadu, India.
E-mail: kumar_kombaiya@rediffmail.com
Reader, Department of Computer Science and Engineering,
Alagappa University, Karikudi, Tamil Nadu, India.

Abstract

This paper presents an approach for an Enhanced Image Compression Method using Partial SPIHT Algorithm. This is based on the progressive image compression algorithm, SPIHT which is an extension of Shapiro's Embedded Zerotree Wavelet Algorithm. The proposed Partial SPIHT Algorithm overcomes the difficulty of SPIHT that loses its efficiency in transmitting lower bit planes. In this paper, we include integer wavelet transformation and region of interest coding to Partial SPIHT and hence make it more superior to SPIHT and EZW Algorithm and it is proved with the results.

Keywords: Integer Wavelet Transform, Hierarchical Trees, SPIHT, Partial SPIHT

Introduction

Increasingly, medical images are acquired and stored digitally. These images may be very large in size and number and compression offers a means to reduce the cost of storage and increase the speed of transmission. Image compression is minimizing the size in bytes of a graphics file without degrading the quality of the image. The resolution 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 download from WebPages.

Several compression algorithms were developed. J.M. Shapiro developed the embedded zerotree wavelet algorithm in [7] which yields a fully embedded code and consistent compression. With embedded coding, it is possible to recover the lossy version with distortion corresponding to the rate of the received image at the point of decoding process. With an extension of EZW, SPIHT algorithm was introduced by Amir and Pearlman in [6]. SPIHT is a progressive image compression algorithm. As quoted in [4] SPIHT is found to have the drawback that the compression decreases during the transmission of lese significant bits. This paper proposes an Enhanced Partial SPIHT algorithm that is based on the probability of significant coefficients within each bit plane and it also includes integer wavelet transform and region of interest coding, ie., ROI-IWT(Region Of Interest – Integer Wavelet Transform) and thereby improves the performance.

The organization of this paper is as follows. An overview of SPIHT algorithm is given in section 2. Section 3 discusses on Integer Wavelet Transform. In section 4, the detail of the proposed method is presented. The proposed method is tested and simulation results are illustrated along with discussions in section 5. Finally, the conclusions are given in section 6.

Overview of SPIHT Coding Algorithm
A simple block diagram of image compression system is shown in Fig. 1.

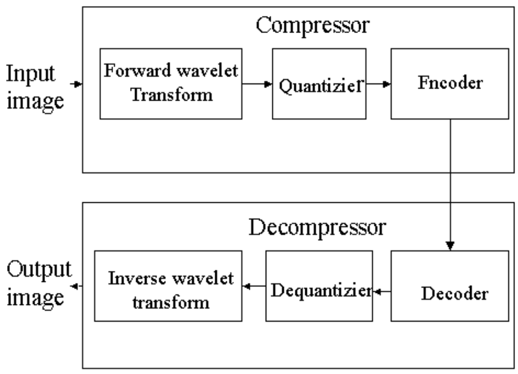

Figure 1: Block diagram of Image compression system.

One of the most important characteristics of DWT is multiresolution decomposition. An image decomposed by wavelet transform can be reconstructed with desired resolution. Fig. 2 shows the four level wavelet decomposition of an image.

When first level 2D DWT is applied to an image, it forms four transform coefficients. The first letter corresponds to applying either low pass or high pass filter to rows and the second letter refers to filter applied to columns. The elimination of high pass components by 2D wavelet transform technique reduces the computation time by reducing the number of arithmetic operations and memory accesses and communication energy by reducing the number of transmitted bits. With the increase in the levels of decomposition, the compression can be made efficient. Correspondingly, the inverse DWT are performed in the decompressor block.

A Quantizer simply reduces the number of bits needed to store the transformed coefficients by reducing the precision of those values. Since this is a many to one mapping, it is a lossy process and is the main source of compression in an encoder. In uniform quantization, quantization is performed on each individual coefficient.

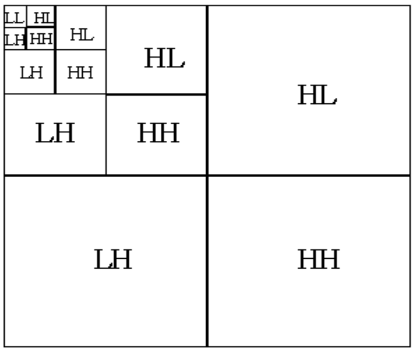

Figure 2: Wavelet Decomposition.

Among the various coding algorithms, the embedded zerotree wavelet coding by Shapiro and its improved version, the SPIHT by Said and Pearlman[6] have been very successful. SPIHT is a progressive image compression algorithm ie., at any moment, the quality of the displayed image is the best available for the number of bits received up to that moment. Compared with JPEG – the current standard for still image compression, the EZW and the SPIHT are more efficient and reduce the blocking artifact. The SPIHT algorithm forms a hierarchical quad tree data structure for the wavelet-transformed coefficients. The set of root node and corresponding descendents are referred to as a spatial orientation tree (SOT) as shown in Fig. 3. The tree is defined in such a way that each node has either no leaves or four offspring, which are from 2 x 2 adjacent pixels. The pixels on the LL sub image of the highest decomposition level are the tree roots and are also grouped in 2 x 2 adjacent pixels. However, the upper-left pixel in 2 x 2 adjacent pixels as in Fig. 3 has no descendant. Each of the other three pixels has four children.

For the convenience of illustrating the real implementation of SPIHT, the following sets of coordinates are defined.

O(i, j): set of coordinates of all offspring of node (i, j).

D(i, j): set of coordinates of all descendants of the node (i, j).

H: set of coordinates of all spatial orientation tree roots (nodes in the highest pyramid level).

L(i, j)=D(i, j)-O(i, j).

Thus, except at the highest and lowest levels, we have

O(i, j)={(2i, 2j), (2i, 2j+1), (2i+1, 2j), (2i+1, 2j+1)}.

Define the following function.

$$S_n(\tau) = \begin{cases} 1, & \max\limits_{(i,j)\in\tau}\{|c_{i,j}|\} \geq 2^n, \\ 0, & \text{otherwise.} \end{cases} \quad (1)$$

$S_n(\tau)$ indicate the significance of a set of coordinates τ, where T(n) is the preset significant threshold used in the nth stage. A detailed description of the SPIHT coding algorithm is given as follows.

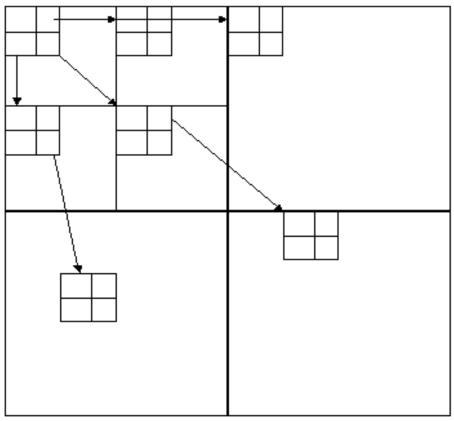

Figure 3: Spatial decomposition Tree.

Initially, T(0) is set to be 2^{M-1}, where M is selected such that the largest coefficient magnitude, say C_{max}, satisfies $2^{M-1} \leq C_{max} < 2^M$. The encoding is progressive in coefficient magnitude for successively using a sequence of thresholds

$T(n)=2^{(M-1)-n}$, n=0,1,…,M-1. Since the thresholds are a power of two, the encoding method can be regarded as "bit-plane" encoding of the wavelet coefficients. At stage n, all coefficients with magnitudes between T(n) and 2T(n) are identified as “significant,” and their positions and sign bits are encoded. This process is called a sorting pass. Then, every coefficient with magnitude at least 2T(n) is "refined" by encoding the nth most significant bit. This is called a refinement pass. The encoding of significant coefficient position and the scanning of the significant coefficients for refinement are efficiently accomplished through using the following three lists: the list of significant pixels (LSP), the list of insignificant pixels (LIP), and the list of insignificant set (LIS). Each entry in the LIP and LSP represents an individual pixel, which is identified by coordinates (i, j). While in the LIS, each entry represents either the set D(i j) or L(i, j). An LIS entry is regarded as of type A if it represents D(i, j) and of type B if it represents L(i, j).

Integer Wavelet Transform

The Discrete Wavelet Transform (DWT) is a versatile signal processing tool that finds many engineering and scientific applications. One area in which the DWT has been particularly successful is in image compression and it has been adopted in the upcoming JPEG2000 image compression standard. Recently the concept of lifting has thrown net insight and ideas on wavelets and has served to enhance the power and versatility of wavelet transforms. Lifting provides an efficient way to implement the DWT and the computational efficiency of the lifting implementation can be up to 100% higher than the traditional direct convolution based implementation. The lifting approach is adopted in JPEG2000. the lifting scheme has also provided an easy way to construct new types of wavelet transforms which can be nonlinear.

The Integer Wavelet Transforms (IWT) maps integers to integers and allows for perfect invertibility with finite precision arithmetic. A simple and effective way to construct IWT is to first factor the traditional DWT into lifting steps and then to apply a rounding operation at each step. The IWT can thus be used for lossless compression of medical images. One of the main advantages of using the wavelet transform for compression is that it provides a multiresolution representation of the image which other techniques like spatial-domain prediction cannot offer. The multiresolution representation allows the transmission of the lower resolution version of the image first, followed by transmission of successive. This mode of transmission is useful when the bandwidth is limited and the image sizes are large, eg. 2D and 3D medical images for telemedicine applications. The transmission can be stopped at the client end if it is deemed that the received image at the current resolution is sufficient or the image is not of interest at the user end. However a full resolution lossless version of the image can be received if so desired. Note that the IWT can also be used for lossy compression and it has certain advantages over the traditional DWT. The IWT can be used in a unified lossy and lossless codec [5] and a seamless transition between virtually lossless and strictly lossless can be achieved. The IWT also have the potential for simpler implementation as many of the operands are integer and hence widely used in compression systems in industries [1].

Proposed ROI-IWT Partial SPIHT Algorithm

The block diagram of encoder part of the proposed ROI-IWT Partial SPIHT algorithm is given in fig. 4.

ROI coding is one of the most important features provided by JPEG-2000. It allows imposing heterogeneous fidelity constraints to different regions of the image rather than encoding the entire image as a single entity. This property is especially useful for image coding applications, where the image consists of regions that can be encoded at different bit rates, such as compression of medical images [2]. For most medical images, the diagnostically significant information is localized over relatively small regions of interest. In this case, region-based coding for better utilization of the available bit rate since the high quality should be maintained only for the aforementioned diagnostically significant regions and the rest of the image can be encoded at a lower bit rate. Once the region of interest is selected efficiently, the significant region is transformed using lossless integer wavelet transform filter and diagnostically unimportant region with lossy Daubechies 5/3 tap filter. Then the transformed images are encoded using Partial SPIHT algorithm, introduced by Abu Hajar and Ravi Shankar in [3]. It is based on the frequency of ones in each bit plane. It uses conventional SPIHT when the frequency of ones is less than 0.2 and two new options are used otherwise. Option_1 is used if the frequency of ones is less than 0.3 and option_2 is used if it is greater than 0.3.The output of Partial-SPIHT encoder is then coded with arithmetic encoder to reduce the redundancy further and to improve the efficiency of compression. The block diagram of ROI-IWT Partial SPIHT decoder is given in fig 5.

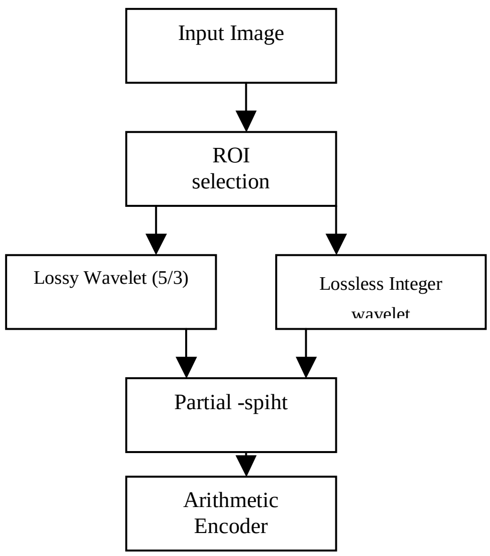

Figure 4: ROI-IWT Partial SPIHT encoder.

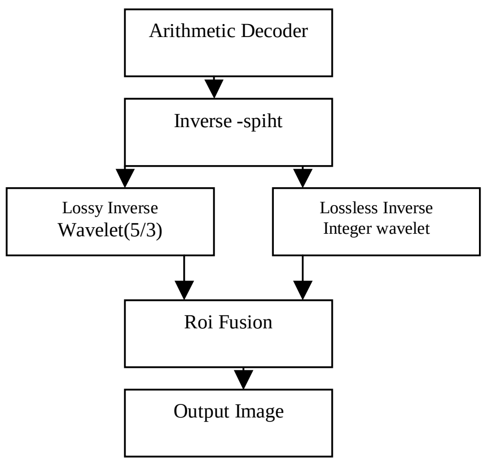

Figure 5: ROI-IWT Partial SPIHT decoder.

The procedure for decoding is exact reverse of the encoding. Experimental results show that the proposed algorithm is superior to SPIHT in both lossy and lossless compression for all tested images.

Simulation Results

8-bit 512x512 images were tested to evaluate the performance of the ROI-based P-SPIHT coder. In order to evaluate the coder effectively, the same ROI region is used for all the tested images. The ROI region has a circular shape and its center is located in the middle of the image, and it occupies about 12% of the total image area. The ROI region is coded using the integer wavelet transform filter and the background is coded lossy using Daubechies 5/3 tap filter. Fig 6(a) and Fig 6(b) shows the lossless and lossy compression of medical images. Fig 7(a) and Fig 7(b) shows the input and reconstructed Images.

Figure 6(a): Lossless.

Figure 6(b): Lossy.

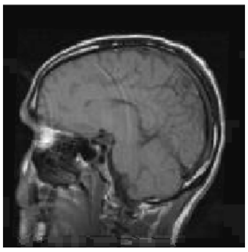

Figure 7(a): Input.

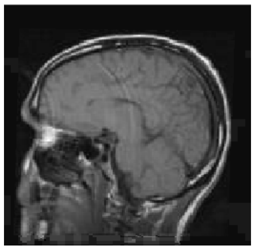

Figure 7(b): Output.

The bit per pixel (bpp) and PSNR for the arbitrary shape region is evaluated by the following.

Bit rate=Total encoded bits/Total number of bits

$$PSNR = 10\log\frac{MAX^2}{\frac{1}{w\times h}\sum_{i=1}^{w}\sum_{j=1}^{h}(o(i,j)-c(i,j))^2} \quad (2)$$

Where Oij is the original image, Cij is the reconstructed image, w is the total number of row elements and h is the total number of column elements, MAX is 255 maximum value of Pixel.

The compression ratio for roi-partial spiht increases than the normal spiht algorithm. The PSNR and CR for the proposed algorithm is shown in Table.1

Table 1: PSNR and CR for SPIHT, EZW and Proposed algorithm.

S.I No	SPIHT		EZW		Proposed	
	PSNR	CR	PSNR	CR	PSNR	CR
C.T	35.12	5:1	39.55	8:1	37	12:1
MRI	34.16	8:1	36.28	16:1	36.1	20:1

Conclusion

In this paper, ROI-based P-SPIHT was proposed which is capable of coding each arbitrary shape ROI regions independently. The compression of the proposed algorithm is superior to SPIHT for lossy as well as lossless coding. This algorithm was compared with other techniques like spiht, modified spiht and embedded zero wavelet. Our coder proves the better performance for medical images in terms of PSNR and CR. In future this work can be extended to medical video compression.

References

[1] Peng Jiang, Qingbo Huang, Yaguang Kang and Li Chai, "Research on Compression Method based on IWT and SPIHT for Historical Data in Process Industry", Computer and Computational Sciences 2006, Proceedings (IMSCCS '06).

[2] Ahmed Abu-Hajar and Ravi Shankar, "Region of Interest Coding using Partial-SPIHT", IEEE 2004.

[3] A. Abu-Hajar and R. Shankar, "Enhanced Partial-SPIHT for Lossless Image Compression" Acoustics, Speech and Signal processing 2003, Proceedings (ICASSP '03)

[4] Abu-Hajar A and Shankar R, "Wavelet based lossless image compression using partial SPIHT and bit plane based arithmetic coder", ICASSP 2002; 4:3497-3500

[5] J. Reichel, G. Menegaz, M. J. Nadenau, and M. Kunt, "Integer Wavelet Transform for Embedded Lossy to Lossless Image Compression". IEEE Trans. Image Proc., 10930:383-392, March 2001.

[6] A. said and W.A. Pearlman, "A New, Fast and Efficient Image Codec Based on Set Partitioning in Hierarchical Trees", IEEE Trans. On Circuit and Systems for Video Technology, 1996.

[7] Shapiro JM, "Embedded image coding using zerotrees of wavelet coefficients", IEEE Trans Signal Processing 1993.