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A Modified SPIHT Algorithm Using Coefficients Thresholding Method for Lossy Image Compression

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Abstract— In modern communicative and network computing, sharing and storing image data effectively are widely used. For sharing, transmitting and storing the image data efficient algorithm can be required to reduce memory requirement, transmission time for fast processing even though, there have been significant development in storage device capacity. Wavelet based image compression technique are widely used for their multi resolution characteristics. Here we have presented an improved modified SPIHT algorithm by using global thresholding and Huffman coding technique. Firstly we have implemented SPIHT algorithm and then applied coefficients thresholding methods at last combined both methods and find out its various parameters and compared them with existing one. We have analysed our result on a natural image having pixel size (256X256) and calculated its compression ratio, bits per pixel and PSNR. Finally we have observed that with the help of proposed algorithm compression ratio and bits per pixel is reduced and picture quality is good.

Keywords— Image Compression, SPIHT, Modified SPIHT, CR, PSNR, BPP.

I. INTRODUCTION

Image compression is getting more and more attention day by day as high speed compression and good quality of image are in high demand. One advantage of an Image compression is to reduce the time taken for transmission of an image. For example, an image has 512 rows and 512 columns. Without compression, totally 512 x 512 x 8 = 2,097,152 bits data needed to be stored. And, each pixel is represented by 8-bit data format. Now to compress it means to reduce the number of bits needed to store those bits without sacrificing a lot for image quality.

The full compression-decompression flow is as shown in Figure.1 Image compression is a problem of reducing the amount of data required to represent a digital image. It is a process intended to yield a compact representation of an image, hereby reducing the image storage/transmission requirement. The reduction in image size allows more images to be stored in given amount of memory space. The main objective of image compression is to find an image representation in which pixel are less correlated. The two fundamental principles used in image compression are reduncy and irrelevancy. Compression is achieved by removal of one or more of the three basic data redundancies [3].

Figure 1 The basic flow of Image Compression system

TYPES OF IMAGE COMPRESSION TECHNIQUES

Digital image compression can be divided mainly in two categories: lossless and lossy compression. Lossless compression is used for artificial images. They use low bits rate. There is a possibility of loss some of the data during this process. While lossless compression is preferred in medical images and military images.

A. Lossy image compression

In lossy compression and decompression methods, accuracy is so important. There will be a data loss but it should be under the limit of tolerance. It should be good enough for application of image processing. This kind of compression is used for transmitting or storing multimedia data, where compromise with the loss is allowed.

B. Lossless image compression

In this type of compression, after decompression the images are almost the same as output images. It can allow the difference between the original image and the reconstructed image up to the certain predefined value. Lossless compression can be a valuable solution where we have strict constrains on the reconstruction. In addition, this method is useful where little information on each pixel is very important.

II. DISCRETE WAVELET TRANSFORM

The fundamental idea behind wavelets is to analyse according to scale. The wavelet analysis procedure is to adopt a wavelet prototype function called an analysing wavelet or mother wavelet. Any signal can then be represented by translated and scaled versions of the mother wavelet. However, in wavelet analysis, the scale that we use to look at data plays a special role. Wavelet algorithms process data at different scales or resolutions. If we look at a signal with a large window, we would notice gross features. Similarly, if we look at a signal with a small window, we would notice small features. The result in wavelet analysis is to see both the forest and the trees, so to speak. This makes wavelets interesting and useful. Wavelets are well-suited for approximating data with sharp discontinuities. The wavelet analysis procedure is to adopt a wavelet prototype function, called an analyzing wavelet or mother wavelet. Temporal analysis is performed with a contracted, high-frequency version of the prototype wavelet, while frequency analysis is performed with a dilated, low frequency version of the same wavelet. Because the original signal or function can be represented in terms of a wavelet expansion, data operations can be performed using just the corresponding wavelet coefficients. A wavelet transform is the representation of a function by wavelets. The wavelets are scaled and translated copies (known as "daughter wavelets") of a finite-length or fast-decaying oscillating waveform (known as the "mother wavelet"). Wavelet transforms have advantages over traditional Fourier transforms for representing functions that have discontinuities and sharp peaks, and for accurately deconstructing and reconstructing finite, non-periodic and/or non-stationary signals. In formal terms, this representation is a wavelet series representation of a square-integral function with respect to either a complete, orthonormal set of basis functions, or an over complete set or Frame of a vector space, for the Hilbert space of square integral functions. The discrete wavelet transform usually is implemented by using a hierarchical filter structure. It is applied to image blocks generated by the pre-processor. Two dimension DWT leads to a decomposition of approximation coefficients at level j in four components: the approximation at level j+1, and the details in three orientations (horizontal, vertical, and diagonal). After DWT transformation the sub band is quantized to further compression and last the coefficient is entropy coded. DWT is used in JPEG 2000 while DCT is used in JPEG algorithm.

III. SET PARTITIONING IN HIERARCHICAL TREES (SPIHT)

The SPIHT coder is a highly refined version of the EZW algorithm and is a powerful image compression algorithm that produces an embedded bit stream from which the best reconstructed images in the mean square error sense can be extracted at various bit rates. Some of the best results—highest PSNR values for given compression ratios — for a wide variety of images have been obtained with SPIHT. Hence, it has become the benchmark state-of-the-art algorithm for image compression [4].

A. Set partitioning sorting algorithm

One of the main features of the SPIHT algorithm is that the ordering data is not explicitly transmitted. Instead, it is based on the fact that the execution path of any algorithm is defined by the results of the comparisons of its branching points. So, if the encoder and decoder have the same sorting algorithm, then the decoder can duplicate the encoder's execution path if it receives the results of the magnitude comparisons, and the ordering information can be recovered from the execution path. One important fact in the design of the sorting algorithm is that there is no need to sort all coefficients. Actually, an algorithm which simply selects the coefficients such that $2n \leq$, $|Ci,j| \leq 2n+1$,with n decremented in each pass. Given n, if $|Ci,j|$, $\geq 2n$ then the coefficient is said to be significant; otherwise it is called insignificant .The sorting algorithm divides the sets of pixels into partitioning subsets Tm and performs the magnitude test

$$\max_{(i\ j)\in Tm} \{|Ci,j|\}>2n$$

If the decoder receives a "no" as that answer, that is the subset is insignificant, then it knows that all coefficients in Tm are insignificant. If the answer is "yes", that is the subset is significant, then a certain rule shared by the decoder and encoder is used to partition Tm into new subsets and the significance test is then applied to the new subsets. This set division process continues until the magnitude test is done to all single coordinate significant subsets in order to identify each significant coefficient.To reduce the number of magnitude comparisons, a set partitioning rule that uses an expected ordering in the hierarchy defined by the sub band pyramid, is used. The objective is to create new partitions such that subsets expected to be insignificant contain a large number of elements, and subsets expected to be significant contain only one element. The relationship between magnitude comparisons and message bits is given by the significance function

$$S_n(T) = \begin{cases} 1, \max\limits_{(i,j)\in T_m} \{|c_{i,j}|\} \geq 2^n \\ 0, otherwise \end{cases}$$

B. Spatial orientation trees

Normally, most of the image's energy is concentrated in the low frequency components. Consequently, the variance decreases as one move from the highest to the lowest of the sub band pyramid. There is a spatial self-similarity between sub bands, and the coefficients are expected to be better magnitude-ordered as one move downward in the pyramid following the same spatial orientation.A tree structure, called spatial orientation tree, naturally defines the spatial relationship on the hierarchical pyramid.

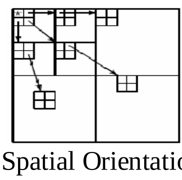

Figure 2 Spatial Orientation Tree

Figure 2 shows how the spatial orientation tree is defined in a pyramid constructed with recursive four-band splitting. Each node of the tree corresponds to a pixel, and is identified by the pixel coordinate. Its direct descendants (offspring) correspond to the pixels of the same spatial orientation in the next finer level of the pyramid. The tree is defined in such a way that each node has either no offspring or four off-springs, which always form a group of 2X2 adjacent pixels. The pixels in the highest level of the pyramid are the tree roots and are also grouped in 2X2 adjacent pixels. However, their offspring branching is different, and in each group one of them (indicated by the star in Fig) has no descendants. Parts of the spatial orientation trees are used as the partitioning subsets in the sorting. With this algorithm the rate can be precisely controlled because the transmitted information is formed of single bits. The encoder can estimate the progressive distortion reduction and stop at a desired distortion value [4-5].

IV. SPIHT ALGORITHM

It is important to have the encoder and decoder test sets for significance .So the coding algorithm uses three lists called SP for list of significant pixels, initialized as empty, IP is list of insignificant pixels for the coordinates of all the root node belongs to root set R, and IS is list of insignificant sets to the coordinates of all the root node in R that have descendants and treated as special type entries.

Procedure:

Step 1: Initialization: Set n to target bit rate.
for each node in IP do:
if Sn [i, j] = 1,
move pixel coordinates to the SP and
keep the sign of ci,j ;
X: for each entry in the IS do the following steps:
if the entry is root node with descendants
if Sn(Des[i, j]) = 1, then
for each offspring (k, i) in Off[i, j] do:
if (Sn(k, i) = 1) then
{ add to the SP,
output the sign of ck,l;}
else
attach (k, l) to the IP;
if (Diff[i, j] <> 0)
{move (i, j) to the end of the IS,
go to X;}
else remove entry from the IS;
If the entry is root node without descendants then output Sn(Diff[i, j]);
if Sn(Diff[i, j]) = 1, then
append each (k, l) in Off(i, j) to the IS as a special
entry and remove node from the IS:

Step 3: Refinement pass: for each entry in the SP, except those included in the last process for sorting, output the nth most significant bit of |i,j|;

Step 4: Loop: reduced n by 1 and go to X if needed

V. PROPOSED SPIHT METHOD

In this proposed method we have combined SPIHT Algorithm with CTM method .First we have applied SPIHT Algorithm on rice Image and then the compressed image will pass through the Coefficients Thresholding method which include the global or level thresholding and then quantization and encoding will applied. Fixed or Huffman coding can be used for the quantization depending on the method. When SPIHT compressed image will pass through global thresholding then its compression ratio will reduced and also bits per pixel is reduced without sacrifices its picture quality.

A. Coefficients Thresholding Methods

The basic idea presented coefficients thresholding methods are used by three methods which are single step, coefficient thresholding (global or by level), and encoding by quantization. Fixed or Huffman coding can be used for the quantization depending on the method. The following table summarizes these methods, often called Coefficients Thresholding Methods (CTM), and gives the MATLAB name used by the true compression tools for each of them.

B. MATLAB Name

'gbl_mmc_f' Global thresholding of coefficients and fixed encoding
'gbl_mmc_h' Global thresholding of coefficients and Huffman encoding
'lvl_mmc' Subband thresholding of coefficients and Huffman encoding

The CTM compression procedure contains three steps:

C. *Decompose:* Choose a wavelet, choose a level N. Compute the wavelet decomposition of the signal at level N.
D. *Threshold detail coefficients*: For each level from 1 to N, a threshold is selected and hard thresholding is applied to the detail coefficients.
E. *Reconstruct:* Compute wavelet reconstruction using the original approximation coefficients of level N and the modified detail coefficients of levels from 1 to N.

The compression features of a given wavelet basis are primarily linked to the relative scarceness of the wavelet domain representation for the signal. The notion behind compression is based on the concept that the regular signal component can be accurately approximated using the following elements: a small number of approximation coefficients (at a suitably chosen level) and some of the detail coefficients.

Quantization refers to the process of approximating the continuous set of values in the image data with a finite, preferably small, set of values. The input to a quantizer is the original data and the output is always one among a finite number of levels. The quantizer is a function whose set of output values are discrete and usually finite. Obviously, this is a process of approximation and a good quantizer is one which represents the original signal with minimum loss or distortion. The key point is that the histogram of the quantized coefficients is massively concentrated in the class centered in 0. Let us note that yet again the image obtained is of good quality. Encoding is the last component in the compression model. This eliminates the coding redundancies.

VI. Experimental Results and Analysis

We have implemented our method on test image named rice having pixel image (256x256).First we have applied SPIHT and then implemented Modified SPIHT and calculated BPP, CR and PSNR for existing SPIHT algorithm and Modified SPIHT. Foll0wing table shows the values of BPP, CR and PSNR using various available filters. We have used MATLAB 2011 wavelet toolbox for implementing these methods. Figure 3, 4 and 5 shows the graph between BPP, CR, PSNR SPIHT algorithm and Modified SPIHT Algorithm. We can see from figure 3 that BPP of modified SPIHT is reduced from the normal SPIHT Algorithm approximately more than 60%.Compression ratio is also redued and PSNR is reduced and picture quality is maintain up to acceptable limits.

TABLE I

BPP, CR And PSNR Values For Spiht And Modified Spiht Algorithm

Wavelet	BPP(SPIHT)	BPP(MSPIHT)	CR(SPIHT)	CR(MSPIHT)	PSNR(SPIHT)	PSNR(MSPIHT)
haar	3.63	1.12	45.43	14.01	41.06	31.04
bior4.4	3.29	1.13	41.16	14.15	40.3	31.01
coif2	3.37	1.1	42.1	13.73	40.48	31.08
sym5	3.36	1.11	41.97	13.86	34.78	29.91
db10	3.4	1.11	42.44	13.89	40.66	31.09

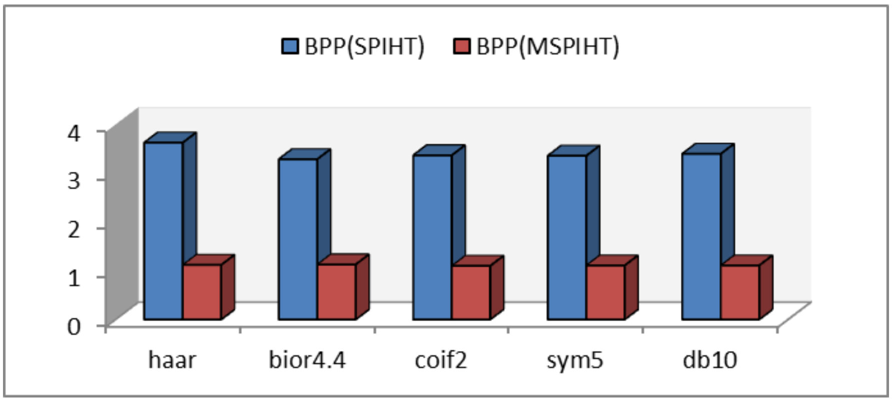

Figure 3 BPP for SPIHT and Proposed Method

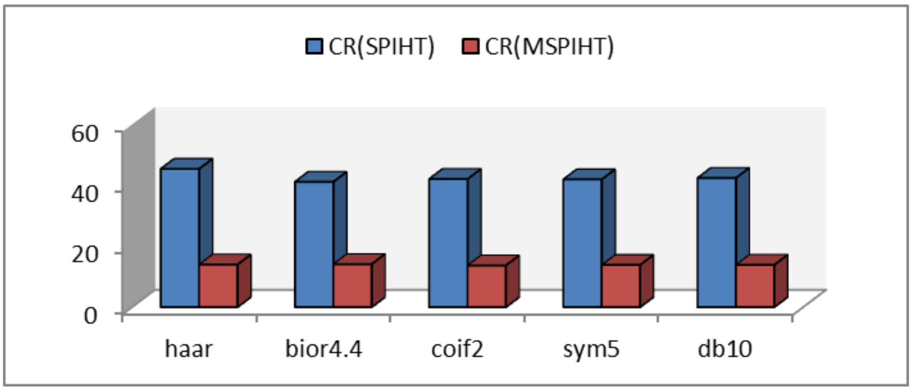

Figure 4 CR for SPIHT and proposed method

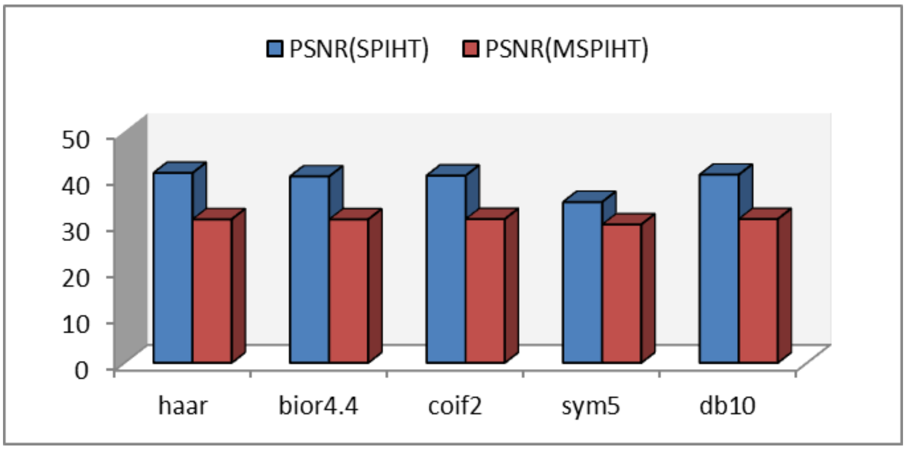

Figure 5 PSNR for SPIHT and Proposed Method

Followings are the graph between CR Vs BPP,CR Vs PSNR and BPP Vs.PSNR.

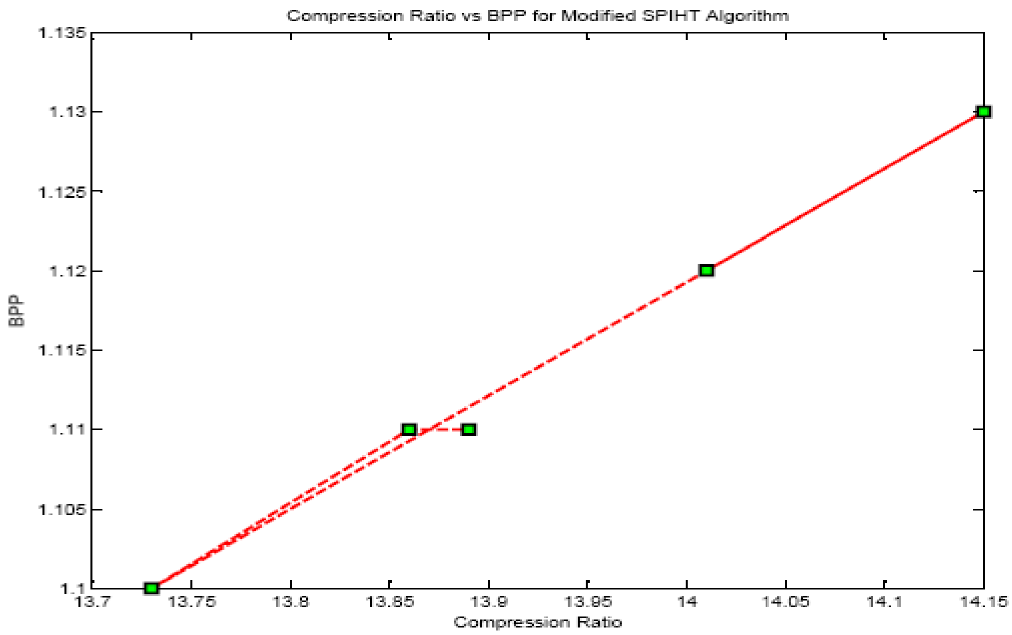

Figure 6 Graph between CR and BPP of Modified SPIHT Algorithm

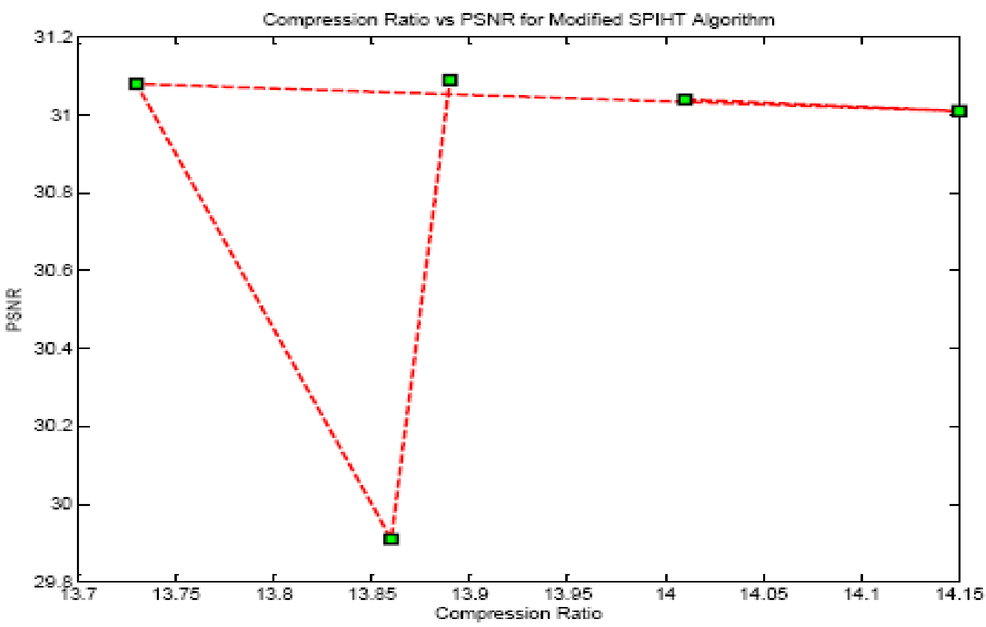

Figure 7 Graph between CR Vs PSNR for Modified SPIHT Algorithm

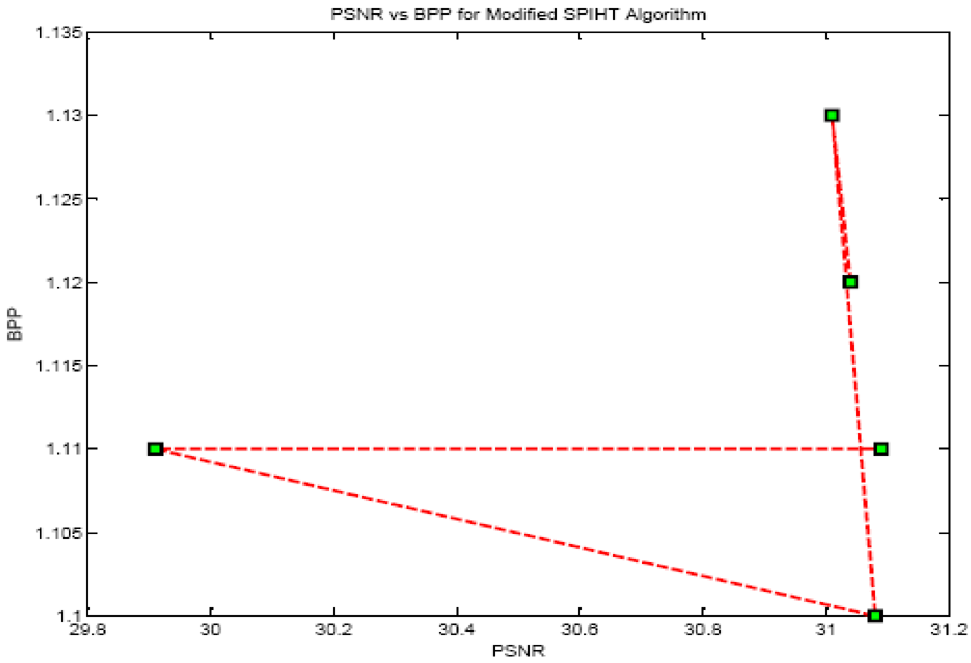

Figure 8 Graph BPP Vs PSNR for Modified SPIHT Algorithm

VII. Conclusion

Although the image compression is a trade-off between compression ratio and peak signal to noise ratio, better and efficient compression-decompression techniques are still in demands in the image processing engineering. Using combination of SPIHT and CTM gives better image quality at low bit rate and at the same time performance can be improved. While compression can be improved further by Huffman entropy encoder (modified SPIHT). Experimental results shows that our proposed approach gives better picture quality and less BPP also storage space is reduced so that we can send more data at a time. So we have been presenting a new image coding algorithm based on the well-known Set Partitioning in Hierarchical Trees (SPIHT), which has been demonstrated to be able to produce better coding performances. The unique feature of this new coding algorithm is to use different (variable) thresholds to sort pixels and initial subsets. Such new sorting procedure is fast and does not require complicated implementations. The outputs of this codec can be further entropy encoded, and therefore can achieve even higher coding performances. The performance of the SPIHT based compression algorithm is hence improved without compromising on the PSNR.

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