Comparison of SPIHT and Lifting Scheme Image Compression Techniques for Satellite Imageries

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ABSTRACT

Wavelets offer an elegant technique for representing the levels of details present in an image. When an image is decomposed using wavelets, the low pass components carry more information than the high pass components. The possibility of better elimination of high pass components gives higher compression ratio for wavelet based techniques. To achieve higher compression ratio, various coding schemes have been considered. The study of 2-D Discrete Wavelet Technique (DWT) architectures reveals that there are two schemes for implementing DWT, one is based on convolution and other based on lifting scheme. . In the present paper a detailed study of the lifting compression scheme for satellite imageries has been carried out. A comparison between the performance of the lifting scheme and SPHIT technique has been made in the context of satellite imageries. For a given compression ratio, the PSNR (peak signal to noise ratio) values are estimated for both the schemes to achieve better quality of the reconstructed image. The results of the analysis demonstrate that for both the schemes, the PSNR values increases with the level of decomposition. The results of the analysis further indicates that for satellite imageries, the lifting scheme is more efficient for obtaining higher compression ratio ~8 and better PSNR values ~29 for achieving good quality of the reconstructed image.

Keywords: DWT, PSNR, EZW, SPIHT, LIFTING SCHEME,

1. INTRODUCTION

The SPIHT algorithm, developed by Said and Pearlman in 1996 [2] is a fast and efficient image compression algorithm works by testing ordered wavelet coefficients for significance in a decreasing bit plane order, and quantizing only the significant coefficients. The high coding efficiency obtained by this algorithm is due to a group testing of the coefficients of a wavelet tree. The SPIHT (Set Partitioning in Hierarchical Trees) algorithm is a refined version of EZW algorithm. It can perform better at higher compression ratios for a wide variety of images than EZW. The algorithm uses a partitioning of the trees in a manner that tends to keep insignificant coefficients together in larger subsets.

The SPIHT algorithm groups the wavelet coefficients and trees into sets based on their significance information. The encoding algorithm consists of two main stages, sorting and refinement. In the sorting stage, the threshold for significance is set as 2n, where n is the bit level, and its initial value is determined by the number of bits required to represent the wavelet coefficient with the maximum absolute value. Significance for trees is obtained by checking all the member detail coefficients. Different architectures have been studied and performance parameters such as PSNR and Compression Ratio are determined. After obtaining double precision value of the image of size 256*256 imagery in BMP format, discrete wavelet transforms techniques are applied to obtain the wavelet coefficients for calculating PSNR and Compression ratio. Inverse Discrete wavelet transform are applied to get back the reconstructed image [10, 11, 2, 13, 14]

2. SPIHT ALGORITHM

The data structure used by the SPIHT algorithm is similar to that used by the EZW algorithm. The wavelet coefficients are again divided into trees originating from the lowest resolution band (band I). The coefficients are grouped into 2 x 2 arrays that, except for the coefficients in band I, are off springs of a coefficient of a lower resolution band. The coefficients in the lowest resolution band are also divided into 2 x 2 arrays. However, unlike the EZW case, all but one of them are root nodes. The coefficient in the top-left comer of the array does not have any offspring.

The trees are further partitioned into four types of sets, which are sets of coordinates of the coefficients:

O (i, j) This is the set of coordinates of the offsprings of the wavelet coefficient at location (i, j).
D (i,j) This is the set of all descendants of the coefficient at location (i,j)
H is set of all root nodes.
L (i,j) This is the set of coordinates of all the descendants of the coefficient at location except for the immediate offsprings of the coefficient at location (i,j).
So,

$$L(i,j)=D(i,j)-O(i,j) \qquad (1)$$

A set D (i, j) or L (i,j) is said to be significant if any coefficient in the set has a magnitude greater than the threshold. The algorithm makes use of three lists: the *list of insignificant pixels* (LIP), the *list of significant pixels* (LSP), and the *list of insignificant sets* (LIS). The LSP and LIS lists contain the coordinates of coefficients, while the LIS contains the coordinates of the roots of sets of type *D or L* .The initial value of the threshold is given as

$$n = \log_2 C_{\max} \qquad (2)$$

Where, C_{max} is the maximum magnitude of the coefficients to be encoded. The LIP list is initialized with the set *H*. Those elements of *H* that have descendants are also placed in LIS as type *D* entries. The LSP list is initially empty. In each pass, the members of the LIP are first processed, then the members of LIS. This is essentially the significance map encoding step. In the refinement step the elements of LSP are processed. Each coordinate contained in LIP is examined first. If the coefficient at that coordinate is significant (i.e., it is greater than 2^n), a 1 is transmitted, followed by a bit representing the sign of the coefficient (1 for positive, 0 for negative). Then that coefficient is moved to the LSP list. If the coefficient at that coordinate is not significant, a 0 is transmitted. After examining each coordinate in LIP, the sets in LIS are examined. If the set at coordinate (i,j*)* is not significant, a 0 is transmitted. If the set is significant, a 1 is transmitted. If the set is of type *D,* each of the offsprings of the coefficient at that coordinate is checked.

For each coefficient that is significant, a 1 is transmitted, the sign of the coefficient, and then the coefficient is moved to the LSP. For the rest a 0 is transmitted and their coordinates are added to the LIP. If this set is not empty, it is moved to the end of the LIS and marked as type *D.* This new entry into the LIS has to be examined during *this* pass. If the set is empty, the coordinate (i, j) is removed from the list. If the set is of type *D,* each coordinate in *D (i,j)* is added *to* the end of the LIS as the root of a set of type *D.* Again, note that these new entries in the LIS have to be examined during this pass. Then (i, j) is removed from the LIS. Once each of the sets in the LIS (including the newly formed ones) is processed, a refinement step is started. In the refinement step each coefficient that was in the LSP *prior to the current pass* is examined and output the nth most significant bit of $| c_{i,j} |$.

The coefficients that have been added to the list in this pass are ignored because, by declaring them significant at this particular level, the decoder has already been informed of the value of the *nth* most significant bit. This completes one pass. Depending on the availability of more bits or external factors, n is decremented *by* one and the process continues.

3. LIFTING SCHEME

The lifting scheme formally introduced by Sweldens[1] is a well-known method to create bi-orthogonal wavelet filters from other ones. Usually, a poly-phase decomposition (or lazy wavelet transform, LWT) of the input signal x0 into sub signals is done, obtaining an approximation signal x and a detail signal y. Then, lifting steps are performed by predicting the detail signal from the x samples and updating the approximation signal with the y samples .The so-called prediction P (or dual lifting) and update U (or primal lifting) steps improve the initial lazy wavelet properties.[1,2,3,4,5,6,7,8,9]

$$y_0[n] = y[n] - p(x[n]) \quad (3)$$

$$x_0[n] = x[n] + U(y_0[n]) \quad (4)$$

Although every reconstruct able filter bank can be expressed in terms of lifting steps, an explicit decomposition for a family of wavelets is only known for the Cohen-Daubechies-Feauveau wavelet.

Peak Signal to Noise Ratio (PSNR): The PSNR is calculated with the following formula

$$PSNR = 10\log_{10}\left[\frac{MaxgreyLevel * MN}{\sum_{xy}|g(x,y) - f(x,y)\,|}\right] \quad (5)$$

Where g (x,y) is the compressed image, f (x,y) is the raw image , M is the image width, N is the image height and max. gray level is the max. value of f (x,y). A Max grey level = 255 has been used (as there are 0 to 255 grey levels represented with 8 bits in the BMP format images).

4. RESULTS AND DISCUSSION

The lifting algorithm was implemented by writing Matlab codes to analyze and synthesize the image in BMP format. For a given image, the lifting algorithm performs the forward DWT to get the filter coefficients (analysis step) and encodes the image. The inverse DWT is performed with the same lifting algorithm to reconstruct the original image (synthesis step). The lifting algorithm is applied to three test images of 256*256 grey scale imageries i.e. ‘lena. bmp’, ‘satellite rural..bmp’ and ‘satellite urban..bmp’. The three test images include the standard Lena image, Satellite urban and Satellite rural imageries have been used for comparison of the two compression techniques namely SPIHT and Lifting schemes.

Using the lifting scheme algorithms ,the DWT coefficients are derived for the three images. For compression ratio of ~8, the PSNR values are computed for different levels of decomposition. The results are as shown in the Figure 2 as well as in the Table 1, 2 & 3.

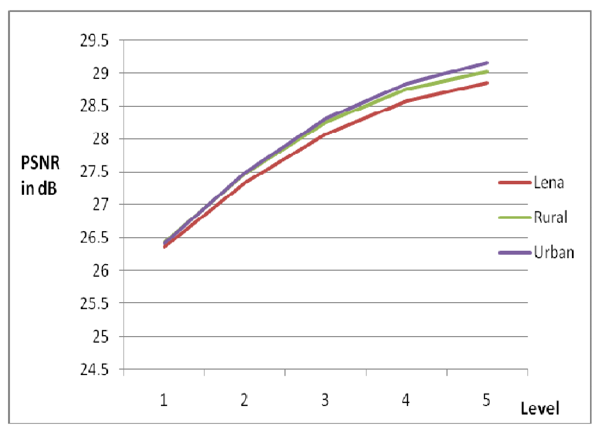

Figure 2. Plot of PSNR in db v/s level for the three different images under study using Lifting scheme.

Table 1. The variation of PSNR in dB and compression ratio for the LENA image using Lifting scheme

Image Type	Level	PSNR in dB	Compression ratio
Lena	1	26.3672	8
	2	27.3388	8
	3	28.0779	8
	4	28.5664	8
	5	28.8505	8

Table 2. The variation of PSNR in dB and compression ratio for the satellite urban image using Lifting scheme

Image	Level	PSNR in dB	Compression ratio
Urban	1	26.4170	8
	2	27.4908	8
	3	28.3176	8
	4	28.8490	8
	5	29.1629	8

Table 3. The variation of PSNR in dB and compression ratio for the satellite rural image using Lifting scheme

Image	Level	PSNR in dB	Compression ratio
Rural	1	26.4255	8
	2	27.4734	8
	3	28.2423	8
	4	28.7420	8
	5	29.0126	8

It is observed from the Figure 2 and Table 1, 2 and 3 that, for the compression ratio, ~8, the PSNR values computed for all the images show slow variation with increase of decomposition levels form 1-5. The range of PSNR values variation observed are with in 10% of the maximum value. The maximum PSNR values achieved for the three types of images are ~29. For the Satellite rural and urban imageries the saturation of PSNR values occurs by the 3rd level. This indicates that for lifting scheme, by increasing the level of decomposition one cannot achieve higher PSNR values for satellite imageries. The compression ratio ~ 8 remains constant for both satellite urban and rural images and the PSNR values are high and produce very good quality of the images irrespective of the origin of the image production. The lifting scheme is ideally suited for compression of satellite imageries for achieving high compression ratio and good quality for the reconstructed images.

5. COMPARISON BETWEEN LIFTING AND SPIHT ALGORITHM

The SPIHT algorithm has been implemented on MATLAB software and tested for three sample images namely: standard Lena image, satellite rural image, satellite urban image. The bit rate is kept constant and level of decomposition is varied from level 1 to level 5. For a maximum compression ratio ~8 and for different levels of decomposition the PSNR values are determined for the three types of images.

The PSNR values derived for different levels of decomposition using the SPIHT algorithm and Lifting scheme for the Lena Image, satellite urban and satellite rural images are shown in Table 4, 5 and 6. For comparison purpose graphs are plotted for the variation of PSNR values with different levels of decomposition derived from both SPIHT and Lifting schemes are shown in Figures 4, 5 and 6.

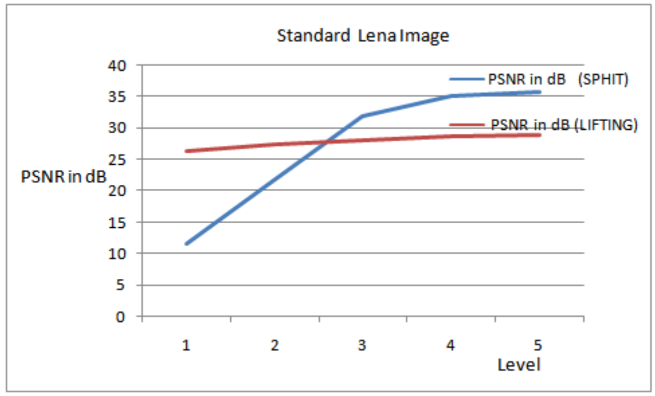

Figure 4. Shows the PSNR variation with decomposition levels derived for SPIHT and Lifting Scheme for Lena image

It is evident from the table 4 and Figure 4 that for the Lena Image the PSNR values derived from SPIHT algorithm increases rapidly from 11.60 to 35.81 dB for decomposition levels from 1-5 and shows a peak value of ~35.81 dB (32%) for the 5th level of decomposition. Where as for the lifting scheme the PSNR values shows a gradual increase in PSNR values from 26.36 and reaches a steady value of 28.08 dB at the 3 rd level of decomposition and peak value of ~ 28.85 dB (97%) for the 5th level of decomposition .

Table 4. The comparison of variation of PSNR in dB for SPHIT and LIFTING schemes for the standard LENA image (Compression Ratio ~8)

Image Type	Level	PSNR in dB (SPHIT)	PSNR in dB (LIFTING)
Lena	1	11.60	26.3672
	2	21.96	27.3388
	3	31.95	28.0779
	4	35.25	28.5664
	5	35.81	28.8505

Similarly for satellite urban image using the SPIHT and Lifting scheme algorithm, the PSNR values has been obtained for different decomposition levels. The PSNR values derived for the image are tabulated in Table 5. The Figure 5 shows the comparison of the two PSNR values for satellite urban image . It is very evident from the table and Figure that the PSNR values derived form SPIHT techniques rapidly increases form 5.7 dB to 19.0dB with the increase of decomposition levels from 1-5.and attains a maximum PSNR value ~ 19.0 dB (30%).Where as the PSNR value for lifting algorithms shows a gradual increase from 26.41 with level of decomposition and indicates steady PSNR value ~28.31dB for the 3 rd level of decomposition and a peak value ~29.16dB (97%) for the 5th level of decomposition. In both the cases further increase in the level of decomposition of the image will not show any improvement in the PSNR.

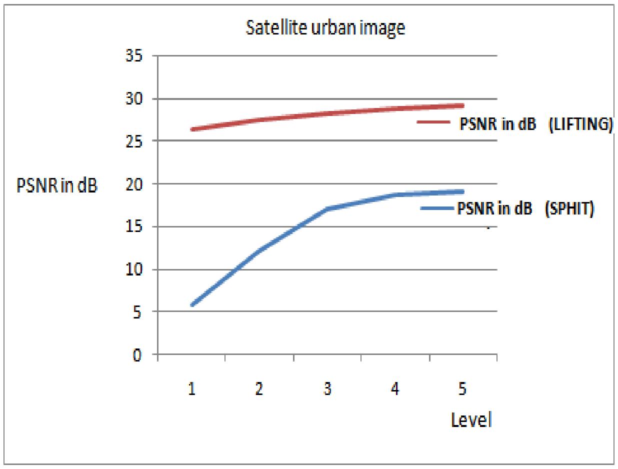

Figure 5. Shows the PSNR variation with decomposition levels derived for SPIHT and Lifting Scheme for Satellite urban image

The PSNR value derived for a satellite rural image at different decomposition levels using the SPIHT algorithm along with the PSNR values derived from Lifting scheme for the same image are shown in the Table 6. The comparison of the PSNR values derived form the two techniques are shown in Figure 6. It is clearly evident from the Table and Figure that the PSNR values derived from SPIHT techniques rapidly increases form 3.7 to 12.6 dB with the increase of decomposition levels from 1-5.and attains a peak PSNR value of ~12.6dB (29%) for the 5th decomposition level. Where as the PSNR derived for lifting algorithms shows a gradual increase in PSNR value from 26.42 and reaches a steady PSNR value ~28.24 dB at the 3rd level of decomposition and peak value ~29.01 (97%). Further increase in the level of decomposition of the image will not show any improvement in the PSNR.

It is evident from the Table 5, 6 that for the SPIHT scheme the maximum PSNR values achievable for both satellite urban and rural image is only ~13dB. In this case the image quality of the reconstructed image will not be very good and cannot be improved further even with the increase of levels of decomposition. Where as the same Table 5, 6 show that for the Lifting scheme for both satellite urban and rural images one can achieve higher values of the PSNR ~ 28 dB even with 3rd level of decomposition.

These results conclusively demonstrate that the lifting schemes achieves higher PSNR values and better quality of the both urban and rural reconstructed satellite imageries compared to that of SPIHT algorithms.

Table 5. The comparison of variation of PSNR in dB for SPHIT and LIFTING schemes for Satellite Urban image (Compression Ratio ~8)

Image Type	Level	PSNR in dB (SPHIT)	PSNR in dB (LIFTING)
Urban	1	5.70	**26.4170**
	2	12.06	**27.4908**
	3	17.00	**28.3176**
	4	18.55	**28.8490**
	5	19.00	**29.1629**

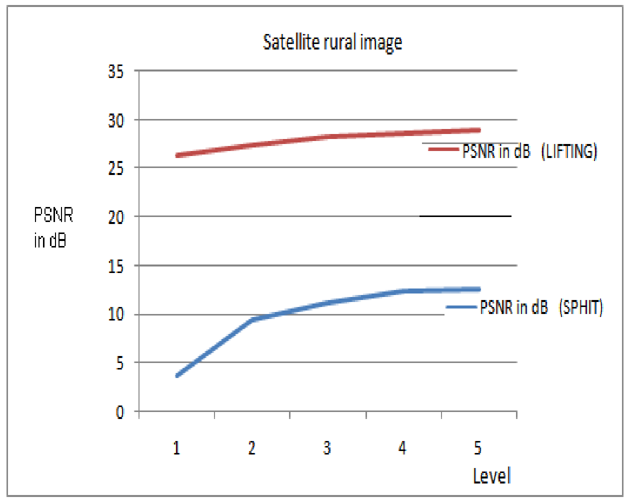

Figure 6. Shows the PSNR variation with decomposition levels derived for SPIHT and Lifting Scheme for Satellite rural image

Table 6. The comparison of variation of PSNR in dB for SPHIT and LIFTING schemes for Satellite Rural image (Compression Ratio ~8)

Image Type	Level	PSNR in dB (SPHIT)	PSNR in dB (LIFTING)
Rural	1	3.70	**26.4255**
	2	9.47	**27.4734**
	3	11.25	**28.2423**
	4	12.40	**28.7420**
	5	12.60	**29.0126**

Figure 7 a Original LENA

Figure 7 b Reconstructed for level 5(SPIHT ALGORITHM) PSNR =35.81

Figure 7 c Reconstructed for level 5(LIFTING SCHEME) PSNR=28.8 db

Figure 8 a Original Image

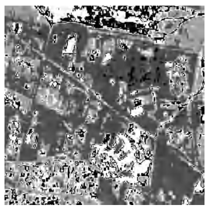

Figure 8 b Reconstructed for level 5(SPIHT ALGORITHM) PSNR =19db

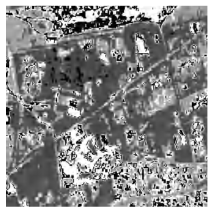

Figure 8 c Reconstructed for level 5(LIFTING SCHEME) PSNR= 29.16dB

The original Lena image and the reconstructed Lena images using the two different compression schemes namely SPIHT algorithm and Lifting scheme for compression ratio of ~8 is shown in Figure 7. It is clearly evident from the Figure that reconstructed Lena image shows better quality of the image for SPIHT scheme (Figure 7b) compared to that of Lifting scheme (Figure (Fig 7c) as the PSNR values achievable for SPIHT scheme is much higher than that of Lifting scheme. For standard images the Lifting schemes do not show better performance compared to the SPIHT. The results indicate that In the case of standard Lena image one can achieve high compression ratio and high PSNR values and better image quality for both SPIHT and lifting scheme compression technique.

Similarly for the original satellite urban image the reconstructed urban images using the SPIHT algorithm and lifting scheme for compression ratio ~8 is shown in Figure 8. It is clearly seen from the Figure 8c that the reconstructed image for lifting scheme shows better quality of the urban image compared to that of SPIHT image shown in Figure 8b as the PSNR values determined are much higher for the Lifting scheme (~ 29.16dB). For satellite urban image the Lifting schemes show better performance compared to the SPIHT. For satellite urban images one can achieve high compression ratio, PSNR values and better image quality using lifting scheme.

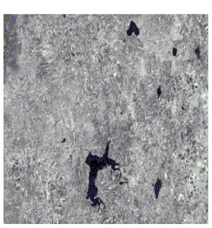

Figure 9 a Original Image

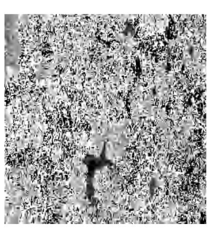

Figure 9 b Reconstructed for level 5(SPIHT ALGORITHM) PSNR =12.6dB

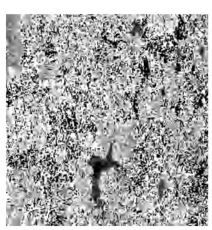

Figure 9 c Reconstructed for level 5(LIFTING SCHEME) PSNR=29.0126dB

The original satellite rural image and the reconstructed rural images after compression using the SPIHT algorithm and lifting scheme for compression ratio ~8 is shown in Figure 9. The figure demonstrates that the reconstructed image for lifting scheme shows better quality of the rural image compared to that of SPIHT image as the PSNR values are higher for the Lifting scheme (~ 29.01dB), It is found that even for satellite rural images the lifting scheme gives better compression ratios, higher PSNR values and better quality of the reconstructed image.

It is evident from the Figures 7, 8 and 9 that the Lifting scheme the is most efficient technique for compression of satellite images for both rural and urban imageries the PSNR values achieved for these images are very high and the quality of the reconstruction of the images are much better than those obtained using SPIHT algorithms. Further the results of the present work illustrates that for satellite imageries high PSNR values are achieved for Lifting schemes at much lower decomposition levels

6. CONCLUSIONS

From the results and discussion presented the following conclusions can be drawn.

1. Lifting schemes are better suited and can be easily adopted for the compression of both satellite urban and rural imageries for achieving significant compression ratios.

2. The PSNR values derived from the SPIHT algorithms for both satellite urban and rural imageries indicate considerably lower values ~19 dB even at higher decomposition levels 5, suggesting that using the SPIHT, it is difficult to achieve higher quality of the reconstructed image.

3. Using the lifting schemes for satellite urban and rural imageries one can achieve higher PSNR values ~29dB even for lower decomposition level 3, .indicating that the lifting schemes are better suited for the compression of satellite imageries.

4. The lifting scheme can produce higher compression ratios (~8), higher PSNR values (~29 dB) and better quality for the reconstructed satellite imageries even at lower levels of decomposition.

7. ACKNOWLEDGEMENT

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