An Efficient Codec of 2d Adaptive Directional Lifting Based Spl5/3 with Improved Spiht Algorithm for Lossless Image Coding

Sanjay H. Dabhole, Sharad T. Jadhav

Abstract— Lifting is an efficient algorithm to implement the discrete wavelet transform in order to overcome the drawbacks of the conventional wavelet transform that does not provide a compact representation of edges which are not in horizontal and vertical directions. The lifting scheme provides a general and flexible tool for the construction of wavelet decompositions and perfect reconstruction filter banks. It has been adopted in JPEG 2000. The paper follows this research line, novel 2 D Adaptive Directional Lifting based on SPL 5/3 has analyzed, structured and tuned with improved SPIHT based on adaptive coding for lossless JPEG 2000 image coding. The proposed 2D-ADL scheme incorporates the directionally spatial prediction into the conventional lifting based on 5/3 wavelet transform and forms a novel, efficient and flexible lifting structure with proposed scaling coefficients. In order to obtain better compression on image edge, an improved Set Partitioning In Hierarchical Trees (ASPIHT) algorithm based on prior scanning the coefficients around which there were more significant coefficients was replaced with conventional SPIHT. Although, the proposed 2D-ADL based on SPL5/3 scheme followed by ASPIHT codec significantly reduce edge artifacts and ringing and outperforms the conventional 1D lifting scheme followed by SPIHT upto 8.4 dB as reported.

Keywords— Adaptive Directional Lifting, SPL 5/3, JPEG 2000, Image Coding, ASPIHT, SPIHT, Compression, PSNR, MSE.

I. INTRODUCTION

Wavelet family is broad. Wavelet basis choice is conditioned by the application at hand or the given objective. In coding, some wavelets are more adequate for smooth regions and others behave better near discontinuities. Hence, many researchers have proposed adaptive schemes that modify the underlying wavelet basis according to local signal characteristics. Filter banks were the fundamental tool to create discrete wavelet transforms. They are formed by the analysis and synthesis low pass and high pass filters and the intermediate stage composed by a down and up sampling. Initially, the complexity and challenge of adaptively was to assure the filter bank reversibility in order to recover the original data. The wavelet transforms with spatially adaptive mother wavelets, chosen according to the underlying local signal characteristics are expected to be more effective in representing such signals.

The lifting framework for wavelet transforms provides the flexibility of designing wavelet transforms with such nonlinear basis functions. Each one dimensional (1-D) Discrete Wavelet Transform (DWT) can be factored in to one or more lifting stages. A typical lifting stage is comprised of four steps: Split, Predict, Update and Normalize. The prediction and update steps in lifting can be made linear or nonlinear. The purpose of this paper is to develop a modified structure L with new simple binary fraction for adaptive lifting based SPL 5/3 and tuned with new modified improved Set Partitioning in Hierarchical Trees (ASPIHT) based on adaptive coding algorithm in which the compression performance is better than existing [1][2] lifting methods and new proposed SPL 5/3-tap wavelet can be considered as a very good alternative to existing lifting wavelets [17 18] for 2 to 8 lifting levels with 0.1 to 1.0 bpp bit rates.

A 2D adaptive lifting structure of DWT is realized by applying the 1D lifting structures to images twice, vertically and horizontally. Iwahashi et O have proposed the 2D direct lifting structure based on 5/3 DWT, by interchanging and merging some lifting in the 2D separable lifting structure of 5/3 DWT [14] [20]. Our proposed scaling coefficients of modified structure of 5/3 DWT 2D adaptive lifting structures was coupled and compressed using ASPIHT for 2D signals such as smooth images like Lena and edge dominated images like peppers.

The proposed 2D adaptive filtering is realized by changing the sampling matrix by sub-regions of images, according to feature directions of the sub-regions. With advantages of the 2D adaptive structure and the adaptive filtering, the proposed structure improves the performance of the lossy image coding application.

Further, In order to obtain better compression on image edge, an improved Set Partitioning In Hierarchical Trees (ASPIHT) algorithm based on prior scanning the coefficients around which there were more significant coefficients was proposed. Finally, lossy image coding results of the proposed codec (2-D ADL+ASPIHT) is compared with previous work done by S.H. Dabhole [17 18] and Wang Tianhui [2] are shown to validate the advantage of the proposed efficient codec.

Section 2 summarizes wavelet transform. We propose adaptive directional lifting structure in Sect. 3, and ASPIHT coding scheme and Compression Quality Evaluation recapitulates in Sect. 4. The implementation of proposed 2D- ADL algorithm has mentioned in section 5. Section 6 summarizes Results and Discussion. Conclusions are presented in Section 7.

Manuscript Received on December 2014.

Sanjay H. Dabhole, Ph.D Scholar, Department of Electronics and Communication, AISECT- Dr. C.V. Raman University, Kota. Bilaspur (C.G.), India.

Sharad T. Jadhav, Ph.D Scholar, Department of Electronics and Communication, AISECT- Dr. C.V. Raman University, Kota. Bilaspur (C.G.), India.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

II. SPL 5/3 WAVELET AND ADAPTIVE LIFTING

The JPEG2000 choice for the lossy-to-lossless compression algorithm (JPEG2000-LDS) is the DWT known as SPL 5/3, spine 5/3. The low- and high-pass analysis filters have 5 and 3 taps, respectively. It was introduced by D. Le Gall [Gal88] in the subband coding domain, seeking short symmetric kernels for PR image coding purposes. Cohen, Daubechies, and Feauveau [7] developed families of biorthogonal transforms involving linear phase filters using Fourier arguments. The shortest biorthogonal scaling and wavelet function with 2 regularity factors (or vanishing moments) at analysis and synthesis is attained with the filter bank proposed by Le Gall. Indeed, the SPL 5/3 synthesis scaling function is a linear B-spline, which is the reason for the name spline 5/3. The SPL 5/3 wavelet also belongs to this family [20].

The SPL 5/3 wavelet analysis low-pass filter H0 (z) and the high-pass filter H1(z) are

$$H_0(z) = \frac{-z^{-2}+2z^{-1}+6+2z^{1}-z^{2}}{8}, \qquad (1)$$

$$H_1(z) = z^{-1}\frac{-z^{-1}+2-z^{1}}{2}.$$

For lossless coding, an integer-to-integer transform [9] is preferred. Lifting with a rounding after each step attains this kind of transform straightforwardly. In this way, any FIR filter bank can be implemented as an integer-to-integer transform by placing the rounding operation after each filter and before the addition or subtraction because of the stated FIR filter bank factorization property into lifting steps [7]. For instance, the lifting steps realize the integer to integer transform of the filter bank. At low bit rates, reversible integer to integer transforms and their conventional counterparts often yield results of comparable quality.

$$P(x[n], x[n+1]) = \left\lfloor \frac{x[n]+x[n+1]}{2} \right\rfloor, \qquad (2)$$

$$U(\acute{y}\,[n-1]), y\,\acute{[n]}) = \left\lfloor \frac{\acute{y}[n-1]+y\acute{[n]}}{4} \right\rfloor.$$

If the initial wavelet is the LWT, then the low and high pass filters are related to the linear prediction and update through

$$H0(z) = 1 + H1(z)U(z^2), \qquad (3)$$

$$H1(z) = z^{-1} - P(z^2).$$

The analysis polyphase matrix of the SPL 5/3 wavelet is

$$H_p(z) = \begin{pmatrix} K1 & 0 \\ 0 & K2 \end{pmatrix}\begin{pmatrix} 1 & \frac{1}{4}z+\frac{1}{4} \\ 0 & 1 \end{pmatrix}\begin{pmatrix} 1 & 0 \\ -\frac{1}{2}-\frac{1}{2}z^{-1} & 1 \end{pmatrix}. \qquad (4)$$

K_2=-1/2. The synthesis filters are

$$G_0(z) = \frac{z^{-1}+2+z^{1}}{2},$$

$$G_1(z) = z\frac{-z^{-2}-2z^{-1}+6-2z^{1}-z^{2}}{8} \qquad (5)$$

Interestingly, the lossless performance is almost independent of the normalization being performed or omitted. However, if the scaling factors are omitted, a performance degradation appear in lossy compression because the transform deviates from unitary and thus, the information con- tent of the coefficients is not directly related to its magnitude. Daubedries and swelden were the first [8] to show the superiority of the biorthogonal wavelet transform 5/3 for the decorrelation of natural images. It has been widely used in image coding [10, 11] and is used by the JPEG-2000 codec. The Lifting scheme of the bi-orthogonal transform 5/3 goes through of four steps: two prediction operators and two update operators as shown it Figure 1 [4, 5].

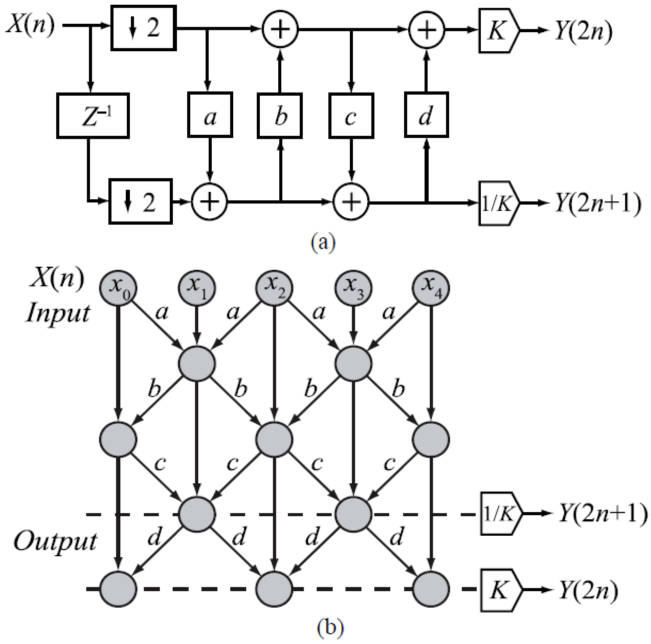


Figure 1 –Split, Predict and Update Steps of forward SPL 5/3 wavelet using Lifting scheme ;(a) Lifting implementation of the analysis side of the SPL 5/3 filter bank ;(b) Structure of the SPL 5/3 filter

The lifting technique is an efficient implementation of wavelet transform with low memory and computational complexity. First of all, we briefly review the conventional lifting technique proposed by Daubechies et al [7]. Let x (*m*, *n*) *m*, *n* Є*Z* be a 2D image. It is well-know that the 2D wavelet transform can be separated into two 1D wavelet transforms without losing the generality, we were only discuss the 1D wavelet transform on the vertical direction. According to the technique proposed in [5], the 1D wavelet transform can be performed with one or multiple lifting stages. A typical lifting stage consists of three steps: split, predict and update. Firstly, all samples are split into two sub-sets: the even sample set and the odd sample set, i.e.

$$\begin{cases} x_e(m,n) = x(m,2n); \\ x_0(m,n) = x(m,2n+1) \end{cases}. \qquad (6)$$

Then, the sample at the odd rows is predicted from the samples at the neighboring even rows. The high-pass coefficient *h* (*m*, *n*) is calculated with

$$h(m,n) = x_0(m,n) - P_e(m,n). \qquad (7)$$

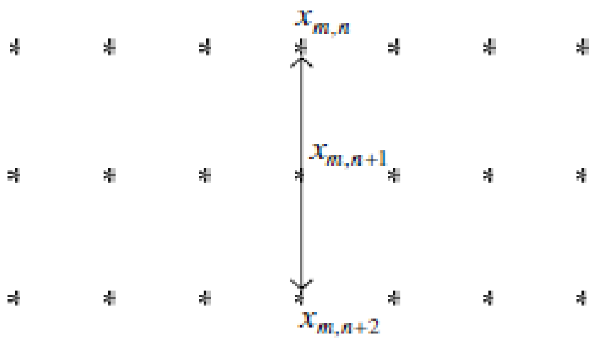
Where $P_e(m,n)$ is the predicting value.

Finally, the sample at the even row is updated with the updating value *Uh* (*m*, *n*) to produce the low-pass coefficient *l*(*m*, *n*) , i.e.

$$l(m,n) = x_e(m,n) + U_h(m,n). \qquad (8)$$

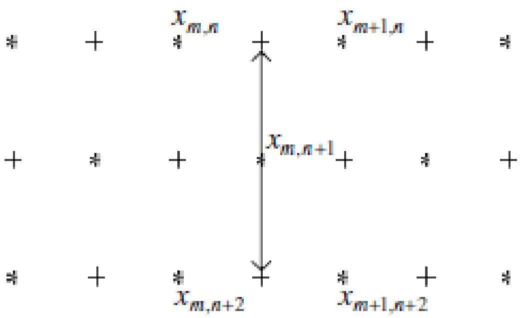
The above lifting steps can be easily applied on a regular image.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.



(a)

Figure 2. (a) Misalignment between even and odd rows



(b)

Figure 2. (b) True pixel locations of even and odd rows

(a) (b)

Figure 3 – First level lifting based decomposition results. (a) Low-pass subband and (b) high-pass subband from the traditional lifting technique;

(c) (d)

Figure 3 (c) low-pass subband and (d) high-pass subband from the proposed lifting technique

However, due to the pixel-misalignment between the even and odd rows in each description from the quincunx segmentation, as shown in Fig. (2), it is not efficient to directly use the conventional prediction and updating lifting operations. Fig. 3(a) and Fig. 3(b) show the low-pass and high-pass sub bands derived from the conventional lifting technique, respectively. Obviously, the high-pass subband is still with relatively larger energy, in that the correlation between neighboring pixels has not been fully exploited. Actually, the true locations of pixels at the even and odd rows are shown in Fig. 2(b). The intuitive solution of tackling the pixel-misalignment problem is to predict $x_{m,n+1}$ from the interpolation values between $x_{m,n}$ and $x_{m+1,n}$ and between $x_{m,n+2}$ and $x_{m+1,n+2.}$ In other words, the prediction direction should be considered in the lifting steps. The similar problem exists in the updating step. Therefore, in this paper, we introduce the interpolation operations into the lifting steps. Actually, more lifting directions are employed to further improve the performance. Fig. 3(c) and Fig. 3(d) show the low-pass and high-pass sub bands derived from the proposed lifting technique, respectively. Obviously, the high-pass subband only has small energy. The proposed adaptive directional lifting transform are described in detail in the next subsection.

III. PROPOSED ADAPTIVE DIRECTIONAL LIFTING STRUCTURE

The proposed directional lifting techniques aims at extensively exploiting the spatial correlation among neighboring pixels in a description. Briefly, the proposed algorithm first analyzes the spatial correlation in all directions for a pixel, and then selects the direction with the smallest prediction errors for the lifting operations. The problem arises from the unavailability of some pixels in some directions in a description. Therefore, the missed pixels have to be interpolated. In this paper, the classical image interpolation algorithm using sinc function is employed. The interpolation is performed up to quarter pixel. Thus, the proposed algorithm analyzes the local spatial correlations in all directions along with predicting horizontal or vertical direction and then chooses a direction with the minimum prediction errors. Fig. 4 shows all prediction directions. The prediction value *Pe* (*m*, *n*) of pixel *x*(*m*,2*n* +1) is taken as a linear combination of the samples at even rows indicated with the arrows. Specially,

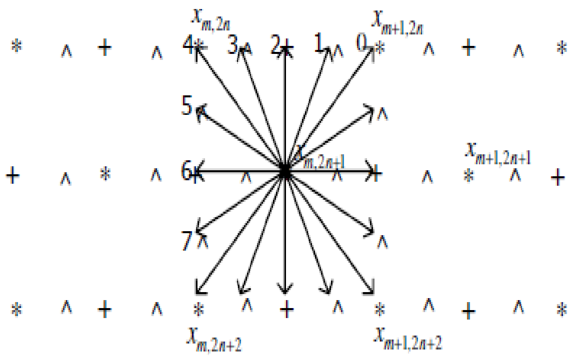
$$P_E(M,N) = \begin{cases} \sum_I P_I X_E\left(M + \frac{2+(-1)^{I-1}(DIR-2)}{4}, N + I\right) \\ \sum_I P_I X_E\left(M + I, N + \frac{2+(-1)^{I}(DIR-6)}{4}\right) \end{cases} \quad (8)$$

Where, the weights *pi* are given by the filter taps, *dir* denotes the prediction direction, and x_e , which is in half-pixel or quarter-pixel precision, is interpolated using adjacent integer pixels by sinc function.

The corresponding finite impulse response function is

$$P(Z_1, Z_2) = \begin{cases} \sum_{I=A}^{B} P_I Z_I \frac{2+(-1)^{I-1}(DIR-2)}{4} Z_2^I & DIR = 1,2,3,4 \\ \sum_{I=A}^{B} P_I Z_1^I Z_2 \frac{2+(-1)^{I}(DIR-6)}{4} & DIR = 5,6,7 \end{cases} \quad (9)$$

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.



Where, *a* and *b* delimit the finite support of the FIR wavelet filter. Since the prediction is still calculated from the samples at even rows, if the prediction direction is known, the proposed lifting can still perfectly reconstruct the samples at odd rows with equation (2).

Figure 4 – The directions in the proposed lifting-based decomposition

The updating step is carried out in the same direction as that in the prediction step. Note that the proposed framework is very general, and it does not have any restriction on the update direction. We keep the prediction and updating direction the same to save the bits to code the side information of direction. Actually, the optimal updating direction should also be consistent with the prediction direction in most cases. Consequently, after the updating step, the samples at even rows are updated as

$$\boldsymbol{U_h(m,n)} = \begin{cases} \sum_j \boldsymbol{U_j h}\left(\boldsymbol{m} + \frac{\boldsymbol{2+(-1)^j(dir-2)}}{\boldsymbol{4}}, \boldsymbol{n+j}\right) \\ \sum_i \boldsymbol{U_j h}\left(\boldsymbol{m+j}, \boldsymbol{n} + \frac{\boldsymbol{2+(-1)^{j-1}(dir-6)}}{\boldsymbol{4}}\right) \end{cases} \quad (10)$$

Where, the weights u_j are given by the filter taps. The corresponding finite impulse response function is

$$\boldsymbol{U(z_1, z_2)} = \begin{cases} \sum_{j=c}^{d} \boldsymbol{U_j} z_1^{\frac{2+(-1)^j(dir-2)}{4}} z_2^j \quad dir = 1,2,3,4 \\ \sum_{j=c}^{d} U_j z_1^j z_2^{\frac{2+(-1)^{j-1}(dir-6)}{4}} \quad dir = 5,6,7 \end{cases} \quad (11)$$

The lifting scheme analysis is described with a sequence of “predict” and “update” filters. Consider a signal X= (x_n) n Є Z with x_n Є R. It is first split into two disjoint sets: the even indexed samples Xe=(x_{2n}) n Є Z and the odd indexed samples Xo=(x_{2n+1}) k Є Z. Typically these two sets are closely correlated. Let a_i(Xe)(where *i*=1,2 in SPL5/3 wavelet) denote the predict operation on Xe, b_i(Xo)(where *i*=1,2 in SPL5/3 wavelet) denote the update operation on X_0. The lifting scheme of SPL5/3 is shown in Fig. 1. In Fig.1, *a*1, *a*2… denote predict filters, and *b*1, *b*2… denote update filters, K and 1/K denotes scaling coefficients. The values of proposed scaling coefficients k_1 and k_2 of modified structure for SPL 5/3 based on adaptive Lifting parameters are:

TABLE-I
Adaptive Lifting parameters of modified structure of SPL 5/3

parameters	values
a	-0.5, -0.5
b	0.25, 0.25
c	0, 1
d	0, -1
$k_{1\ \text{Proposed}}$	1 and
$k_{2\ \text{Proposed}}$	0.5

The synthesis side of the filter bank simply inverts the scaling, and reverses the sequence of the lifting and update steps. Fig. 5 shows the synthesis side of the filter bank using lifting.

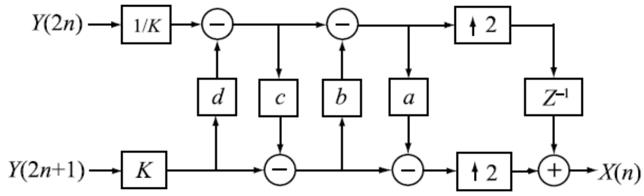


Figure 5 – Lifting implementation of the synthesis side of the SPL 5/3

IV. ASPIHT CODING SCHEME

When the decomposition/forward lifting image is obtained, we try to find a way to code the wavelet coefficients into an efficient result, taking redundancy and storage space into consideration. SPIHT [7] is one of the most advanced schemes available, even outperforming the state-of-the-art JPEG 2000 in some situations. The basic principle is the same; a progressive coding is applied, processing the image respectively to a lowering threshold. The difference is in the concept of zero trees (spatial orientation trees in SPIHT). This is an idea that takes into consideration bounds between coefficients across sub bands at different levels [19]. The first step is always the same: if there is a coefficient at the highest level of the transform in a particular subband which considered insignificant against a particular threshold, it is very probable that its descendants in lower levels will be insignificant too. Therefore we can code quite a large group of coefficients with one symbol. Fig. 6 shows the algorithm of SPIHT is discussed as a First step; the original image is decomposed into ten sub bands. Then the method finds the maximum and the iteration number. Second, the method puts the DWT coefficients into a sorting pass that finds the significance coefficients in all coefficients and encodes the sign of these significance coefficients. Third, the significance coefficients that can be found in the sorting pass are put into the refinement pass that uses two bits to exact the reconstruct value for approaching to real value. The first second and third steps are iterative, and then iteration decreases the threshold $(T_n = T_{n-1}/2)$ and the reconstructive value$(R_n = R_{n-1}/2)$.

In order to obtain better compression on image edge, an improved Set Partitioning In Hierarchical Trees (ASPIHT) algorithm based on prior scanning the coefficients around which there were more significant coefficients was proposed [19]. The coefficients or sets were sorted according to the number of surrounding significant coefficients before being coded, and the previous significant coefficients were refined as soon as the sets around which there existed any significant coefficients had been scanned. The scanning order was confirmed adaptively and did not need any extra storage. It can code more significant coefficients at a specified compression ratio. As a fourth step, the encoding bits access entropy coding and then transmit [11].

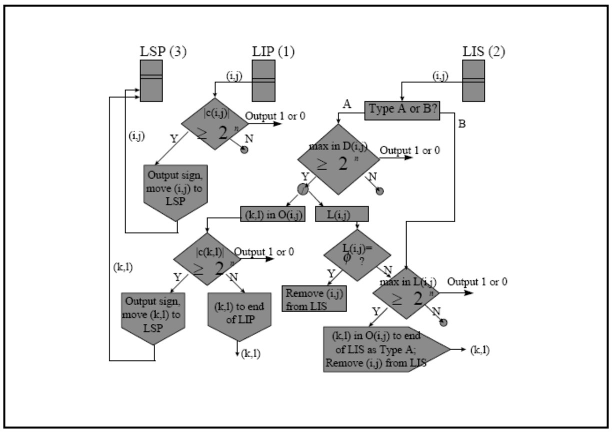


Figure 6 – SPIHT algorithm

The result is in the form of a bit stream. The entire wavelet based image encoding algorithms improves the Compression rate and the visual quality.

V. IMPLEMENTATION OF PROPOSED CODEC ALGORITHM

We were proposed a two dimensional (2D) adaptive Lifting based on SPL 5/3 with modified structure i.e. scaling coefficient L=[k1,k2] with $K_{1proposed}$=1 and $K_{2proposed}$= 0.5 for lossy Image compression, as shown in figure 7 Furthermore, by introducing the adaptive lifting to the modified structure, the 2D proposed structure was realized and applied along with ASPIHT into lossy image compression.

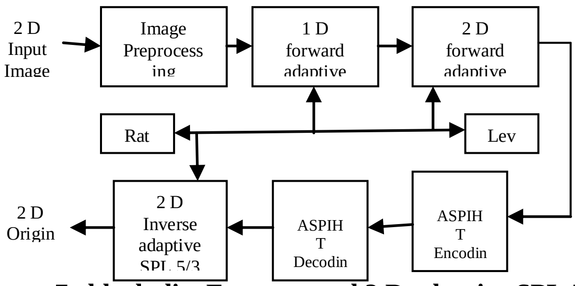


Figure 7– block dia. For proposed 2 D adaptive SPL 5/3 wavelet with spiht for lossy image compression

ASPIHT not only has longer wavelet zero tree but also can more efficiently cluster wavelet zero coefficients and will itself improve upto 2.5db PSNR and the subjective visual experience compared with conventional SPIHT.

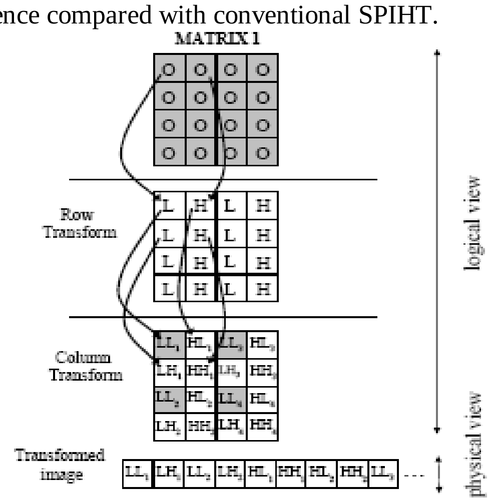


Figure 8– In place strategy (logical view on the top; recursive data layout on the bottom)

Two types of DWTs are considered in the JPEG2000: the lossless algorithm is based on an integer Spine 5-tap/3-tap filter, whereas the lossy compression uses the popular Daubechies 9-tap/7-tap floating-point filter [4].In order to avoid this rearrangement overhead, we have also considered two additional strategies. The first one, which we have denoted by ADL, was proposed in [18]. It uses an auxiliary matrix to store the results of the horizontal (row) filtering. In this way, as figure 9 shows, the horizontal high and low frequency components are not interleaved in memory. The vertical (column) filtering reads these components and writes the results into the original matrix following the order expected by the quantization step.

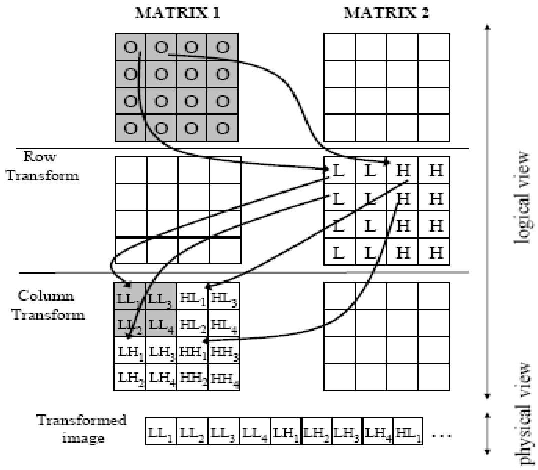


Figure 9– ADL strategies (logical view on the top; recursive data layout on the bottom)

In order to improve data locality we have employed a recursive data layout [19] where each sub-band is laid out contiguously in memory. As we will explain below, this approach also allows a better exploitation of the ADL parallelism. Furthermore, we have introduced an additional strategy, which we have denoted by in place ADL. It can be considered as a trade-off between the in place and ADL alternatives.

It performs the horizontal filtering in place but uses an auxiliary matrix to store the final wavelet coefficients as soon as they are computed. In this way, at the end of the calculations, the transformed image is stored in the expected order, thus avoiding the post processing stage. As above, a recursive data layout is employed in order to improve data locality. Figure 10 graphically describes this alternative. Only the low frequency components in each direction (denoted by LL) are stored in the original matrix (apart from the deepest decomposition level) whereas the other components (denoted by LH, HL and HH) are moved into the auxiliary matrix in their correct final positions. The recursive data layout benefits the spatial locality of the memory access pattern. Nevertheless, further data locality improvements are possible by means of loop tiling (aggregation in fig.4).

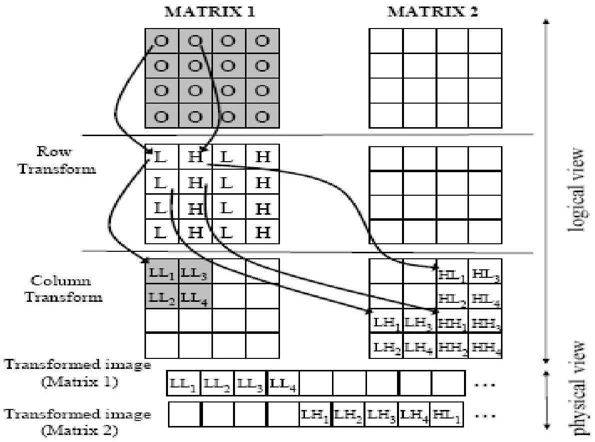


Figure 10– AD L column strategy (logical view on the top; recursive data layout on the bottom)

Supposing a column-major layout on every wavelet sub-band (the whole image for the in place strategy), memory access becomes a bottleneck in the horizontal filtering. In order to reduce this overhead, instead of processing the image rows one after the other, which produces very low data locality, the horizontal filtering is applied column by column so that the spatial locality can be more effectively exploited.

Algorithm for proposed Codec

- Read the Image from the database
- Preprocessing of given image
- Call the adaptive directional wavelet lifting using the lossy SPL 5/3 wavelet for forward transform
  - checking the Input arguments
  - forming adaptive directional lifting structure and lifting mode set the direction for forward directional lifting
  - first lift all columns of given image
    - compute the lift and right shifts needed for given image
    - get even and odd subsequences with extensions to be lifted
    - do the additional input pre-treatment for inverse lifting
    - do the adaptive core lifting process
    - do the additional post-treatment for inverse lifting
    - process the output
- Call ASPIHT encoding for coding and transformation for JPEG 2000 image coder
- call ASPIHT decoding for coding and transformation for JPEG 2000 image coder
- Call the adaptive directional wavelet lifting using the lossless SPL5/3 wavelet for reverse transform
  - Perform inverse directional lifting for all rows using column 2-D lifting using ADL function and repeat same procedure for all columns
- Display the forward and reverse transformed output images
- Calculate PSNR of whole module of ADL for JPEG 2000 codec.

Compression Quality Evaluation: The Peak Signal to Noise Ratio (PSNR) is the most commonly used as a measure of quality of reconstruction in image compression. The PSNR are identified using the following formulate:

$$\mathrm{PSNR} = 10\log_{10}\left(\frac{(\text{Dynamics of image})^2}{\mathrm{MSE}}\right) \qquad (9)$$

Mean Square Error (MSE) which requires two $M \times N$ grayscale images I and $\hat{I}$, where one of the images is considered as a compression of the other is defined as:

$$MSE^2 = \frac{1}{M \times N}\sum_{I=1}^{i=M}\sum_{j=1}^{j=N}\left(I(i,j) - \hat{I}(i,j)\right)^2 \qquad (10)$$

Here, an image is encoded on 8 bits. It is represented by 512 gray levels, which vary between 0 and 511, the extent of image dynamics is 512.

VI. RESULTS AND DISCUSSION

We are interested in lossless compression methods based on 2D wavelet transforms because their properties are interesting. Indeed, the 2D wavelets transform combines good spatial and frequency locations. We applied the proposed algorithm on test image 'Lena' and 'peppers of size 512 X 512 encoded by 0.25 to 8 bit rates in bpp for levels from 1 to 8.

The importance of our work lies in the possibility of reducing the rates for which the image quality remains acceptable. Estimates and judgments of the compressed image quality are given by the PSNR evaluation parameters shown below in table –II for Lena and table-III for peppers.

TABLE-II

PSNR of ADL based 5/3 CDF at 2 to 8 levels with different rates for Lena

Rate	level	2	4	6	8
0.25	Wang Tianhui [2]	15.75	30.24	28.14	27.44
	S.H. Dabhole[17] (1D ADL+SPIHT)	17.22	29.04	28.88	27.84
	Proposed (2D ADL+ASPIHT)	18.41	34.34	34.20	33.41
0.50	Wang Tianhui [2]	16.97	34.56	32.79	30.27
	S.H. Dabhole[17] (1D ADL+SPIHT)	22.51	36.62	35.25	34.06
	Proposed (2D ADL+ASPIHT)	23.73	40.83	39.42	38.14
1.0	Wang Tianhui [2]	25.90	40.42	38.63	36.92
	S.H. Dabhole[17] (1D ADL+SPIHT)	27.41	37.69	39.73	37.69
	Proposed (2D ADL+ASPIHT)	29.77	43.12	41.84	40.47

To show the performance of the proposed method, we will now make a comparison between our proposed scheme of 2D-ADL based SPL 5/3 coupled with the ASPIHT coding, with previous work of myself[17] which comprises 1D-ADL with conventional SPIHT , existing lifting structures of SPL 5/3 of Wang Tianhui[2].

TABLE-III
PSNR of ADL based 5/3 CDF at 2 to 8 levels with different rates for peppers

Rate	level	2	4	6	8
0.25	Wang Tianhui [2]	11.47	31.86	33.46	33.48
	S.H. Dabhole[17] (1D ADL+SPIHT)	12.07	33.08	31.29	22.09
	Proposed (2D ADL+ASPIHT)	11.82	34.02	34.36	30.90
0.50	Wang Tianhui [2]	13.28	35.36	36.23	36.25
	S.H. Dabhole[17] (1D ADL+SPIHT)	16.13	39.80	38.74	28.74
	Proposed (2D ADL+ASPIHT)	18.58	39.91	40.37	37.20
1.0	Wang Tianhui [2]	22.36	40.07	40.64	40.66
	S.H. Dabhole[17] (1D ADL+SPIHT)	19.90	41.34	40.53	34.83
	Proposed (2D ADL+ASPIHT)	25.46	43.94	43.64	43.23

VII. CONCLUSIONS AND FUTURE SCOPE

The proposed codec (2D-ADL+ASPIHT) appears promising for image compression. Table II at level=8 and rate=1 confirms better performance for smooth images like Lena that gives much better PSNR from 3.22 to 4.8 db than traditional [17][2].

Similarly, table-III at level= 8 and rate=1 seems that it reduces edge artifacts and ringing for edge dominated images like peppers and gives improved PSNR of 8.4 dB than the previous work [17][2].

Further, all this can be achieved without extra cost on coding the filter decisions. This proposed method does not require any side information regarding to the filter selection to be sent to the backward transform for perfect reconstruction.

From the above discussion, it is evident that the 2D adaptive lifting based wavelets coupled with ASPIHT outperform the traditional lifting wavelets. The future scope of the presented work can be summarized as follows.

- The techniques can be extended for video compression.
- The techniques can be extended for any other image processing applications for better results.

VIII. ACKNOWLEDGMENTS

This paper is partly supported by Research and Development Cell of Electronics and Communication Engineering Department of Dr. C.V. Raman University, Kota. Bilaspur (C.G.), INDIA.

REFERENCES

1. D.S.Taubman et al., *JPEC2000 Image Compression: F. S. & P.*, Chinese Edition, section 6.4, 6.5, 10.3 and 10.
2. Wang Tianhui., Self-contained 2-D image decomposition and reconstruction based on lifting wavelet algorithm from Matlab file Exchange website
3. Claypool, R.L... Baraniuk R., and Novak R., (1998) "Adaptive wavelet transform via lifting," *International Conference on Acoustics, Speech and Signal Processing*, , vol. 3, pp. 1513– 1516.
4. Claypool, R.L Davies, G. Sweldens, and. Baraniuk, R. (1999)"Lifting for nonlinear image processing," *Wavelet Applications in Signal and Image Processing* VII, , vol. Proc. SPIE 3813,pp. 372– 383.
5. Claypool, R.L... Davis, G. M. Sweldens, W.and Baraniuk, R. G. (2003) "Nonlinear wavelet transforms for image coding via lifting," *IEEE Transactions on .Image Processing*, vol.12, no. 12, pp.1449–1459,
6. A. Said and W. A. Pearlman, "A new, fast, and efficient image codec based on set partitioning in hierarchical trees," *IEEE Trans. Circuits Syst. Video Technol.*, vol. 6, no. 3, pp. 243-250, June 1996
7. Daubechies I. and. Sweldens, W. (1997.) "Factoring wavelet transform into lifting steps," *Journal of Fourier analysis and Applications* vol.4, no. 3, pp. 245–267,
8. R. L. Claypoole Jr., J. M. Davis, W. Sweldens, and R. Baraniuk,"B-spline signal processing: Part II—Efficient design and applications," IEEE Trans. Signal Processing, vol. 41, pp. 834–848, Feb. 1993.
9. Omer N.Gerek and Enis Cetin. A,(2006) ," A 2-DOrientation Adaptive- Prediction Filter in Lifting Structures for Image Coding", *IEEE Transactions on Image Processing*, vol.15,No 1 pp.106- 111
10. Piella G.and Heijmans, H. J. A. M. (July. 2002) "Adaptive lifting Schemes with perfect reconstruction," *IEEE Transactions on Sign Processing*, vol. 50, no. 7, pp 1620– 1630,.
11. Said A. and William A. Pearlman.,(1996), "A New, Fast Efficient Image Codec Based Set Partitioning Hierarchical Trees", *IEEE Transaction on Circuit and Systems for Video Technology*,vol.6 No.3,pp 243-250
12. Shaoyu Zheng, Fang Xu, Deqing Wang (2009) "An Improved Adaptive Lifting Scheme Combining Gradient Operator for Image Coding 1st *International conference on information science and engineering* vol.1, pp-1133-1136.
13. V. A. Zheludev, "Local spline approximation on a uniform grid,"U.S.S.R. Comput. Math. & Math. Phys., vol. 27, pp. 8–19, 1987.
14. Danyali H, Mertins "A family of polynomial spline wavelet transforms," *Signal Processing*, vol. 30, pp. 141–162, 1993.
15. Xiaoyuan Yang, Zhipin Zhu, Bo Yang,(2008) "Adaptive Lifting Scheme for Image Compression, *Fifth International Conference on Fuzzy Systems and Knowledge Discovery*, vol. 1, pp.547-551
16. Said, W.A. Pearlman: A New, Fast and Efficient Image Codec based on Set Partitioning in Hierarchical Trees, IEEE Transaction on Circuits and Systems for Video Technology, Vol. 6, No. 3, June 1996, pp. 243 – 250.
17. Sanjay H. Dabhole, , Johan Potgieter, An efficient modified structure of SPL 5/3 wavelet based on adaptive lifting with spiht for lossless image compression. *IEEE explore digital library* of *Signal Processing, Image Processing and Pattern Recognition* -2012.
18. Sanjay H. Dabhole, Johan Potgieter, Performance evaluation of traditional and adaptive lifting based wavelets with spiht for lossy image compression, *IEEE explore digital library of Signal Processing, Image Processing and Pattern Recognition*-2012.
19. "Huang Ke-kun. Improved Set Partitioning in Hierarchical Trees Algorithm Based on Adaptive Coding Order [J], Journal of Computer Application-china, 2012, 32(3):732-735.
20. Y. Y. Zeevi and R. Coifman, Eds.,San Diego,"Periodic splines, harmonic analysis, and wavelets," in Signal and Image Representation in Combined Spaces, Wavelet Anal. Appl., , CA: Academic, 1998, vol. 7, pp. 477–509.

Prof. Sanjay H. Dabhole, last six years working as Principal in Sant Gajanan Maharaj Rural Polytechnic, Mahagaon, Gadhinglaj Tahsil, dist-Kolhapur. (M.S), INDIA, obtained his Bachelor's Degree of Electronics Engineering in 2002 from Walchand College of Engineering Sangli at Shivaji University, Kolhapur M.S., and took his Masters Degree of Electronics and Telecommunication Engineering in 2006 from KIT C.O.E. of Shivaji University Kolhapur with first rank, M.S. Currently, he is pursuing Ph.D from Electronics and Communication Dept. AISECT- Dr. C.V. Raman University, Kota. Bilaspur (C.G.), INDIA. I have total 12 years of teaching experience at various technical institutes and setup new Sant Gajanan Maharaj Technical campus in all aspects within 4 years. National level Best Teacher award on occasion of World teachers' day on 5th Oct. 2014 from Aviskar Social was Received and Educational Foundation Kolhapur (M.S.), INDIA. I am life time member of The Institution of Engineers, India.(IEI) apex body And his area of interest is Signal & Image Processing. To his credit 12 papers have been published in International & National Conferences and six papers have been published in International journals including IEEE explore whose impact factor is more than 1.0.

Prof. Sharad T. Jadhav, last six years working an I/c Head and Asst. Professor in Dept. of Electronics and Telecommunication at Sanjeevan Engg. & Tech. Institute, Panhala. Dist-Kolhapur. (M.S), INDIA, obtained his Bachelor's Degree of Electronics Engineering in 2001 from Shivaji University, Kolhapur M.S., and took his Masters Degree of Electronics and Telecommunication Engineering in 2007 from KIT C.O.E. of Shivaji University Kolhapur. (M.S.) Currently, he is pursuing Ph.D from Electronics and Communication Dept. AISECT- Dr. C.V. Raman University, Kota. Bilaspur (C.G.), INDIA. I have total 13 years of teaching experience at various technical institutes I am life time member of ISTE and IETE New Delhi apex body and his area of interest is Bio-medical & Image Processing. To his credit 10 papers have been published in International & National Conferences and one paper has been published in IJEA, Vol. 3, Special Issue 1, ISSN: 2320 – 0804(o) International journal