Study of A Image Compression Based on Adaptive Direction Lifting Wavelet Transform Technique

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***Abstract*— For image compression, it is very necessary that the selection of transform should reduce the size of the resultant data as compared to the original data set. For continuous and discrete time cases, wavelet transform has emerged as popular techniques. While integer wavelet using the lifting scheme significantly reduces the computation time, a completely new approach for further speeding up the computation. We present a novel 2-D wavelet transform scheme of adaptive directional lifting (ADL) in image coding. Instead of alternately applying horizontal and vertical lifting, as in present practice, ADL performs lifting-based prediction in local windows in the direction of high pixel correlation. Hence, it adapts far better to the image orientation features in local windows. The ADL transform is achieved by existing 1-D wavelets and is seamlessly integrated into the global wavelet transform. The predicting and updating signals of ADL can be derived even at the fractional pixel precision level to achieve high directional resolution, while still maintaining perfect reconstruction. To enhance the ADL performance, a rate-distortion optimized directional segmentation scheme is also proposed to form and code a hierarchical image partition adapting to local features. Experimental results show that the proposed ADL-based image coding technique outperforms JPEG 2000 is improvement up to 2.0 dB on images with rich orientation features.**

***Keywords*—Adaptive directional lifting (ADL), image coding, wavelet transforms, Discrete cosine transform (DCT), discrete wavelet transform (DWT), image compression, set - partitioning in hierarchical trees (SPIHT).**

I. Introduction

The Image compression is an important in the life with the rapidly increasing in the amount of digital camera. Different types of compression schemes from early DPCM-based (Differential Pulse Code Modulation) [1] to DCT-based [2], again to wavelet-based [3], have been developed in past decades. The DCT-based schemes, like JPEG [2], usually offer a low computation solution, but they difficultly achieve the desired scalabilities. In comparison with the DCT-based schemes, the wavelet based schemes need more computational power. On the other hand, the wavelet transform provides a multiscale representation of images in the space-frequency domain. A major advantage of the wavelet transform is its inherent scalability. For example, the wavelet-based JPEG2000 standard [4] not only presents superior compression performance over the DCT-based JPEG standard, but also offers scalabilities in rate, quality and resolution that are very desirable for network applications.

So the 2-D discrete wavelet transform (DWT) is the most important new image compression technique of the last decade [5]. Conventionally, the 2-D DWT is carried out as a separable transform by cascading two 1-D transforms in the vertical and horizontal direction.

An adaptive wavelet transform that can be adapts the transform directions to image content is presented in [4]. The image is partitioned into blocks. Each image block is then sheared through a reversible resampling filter such that the edges in the sheared block are oriented either vertically or horizontally.

An important technique that enables a locally adaptive wavelet transform while allowing filtering across block boundaries as well as a regular subsampling grid is *lifting*, a procedure to design DWTs that are ensured to achieve perfect reconstruction [6]. Using lifting, several approaches have been developed to locally adapt the filter coefficients [7], or the filtering directions [8], such that filtering is not performed across edges in the image.

These approaches eliminate the need for signaling the filter selections to the decoder by assuming lossless compression [8] or knowledge of the quantization noise at the encoder or constraining the selection process such that it can be reliably repeated at the decoder.

Other approaches that also adaptively select the filtering directions via lifting choose to explicitly signal the selections to the decoder [9]. In this category, we have independently developed an approach that combines directional lifting with quincunx subsampling.

II. ADAPTIVE DIRECTION LIFTING DWT

Consider the adaptive direction no longer limited to horizontal and vertical directions. We select the set of direction as in Fig. 1. In this Fig. 1, the white points represent odd samples and the black points represent even samples.

Here, only check for horizontal or vertical discrete direction between −45° to 45°, because we found that the absolute degrees which are greater than vertical direction degrees can be achieved by the absolute degrees that are less than horizontal direction.

In this way, if there are two different direction characteristics in the image, we can use a direction parallel horizontal direction, and then choose the other direction to adjust vertical direction.

Adding such a direction to select the structure in the basic structure of the ADL wavelet of split, predict and update steps.

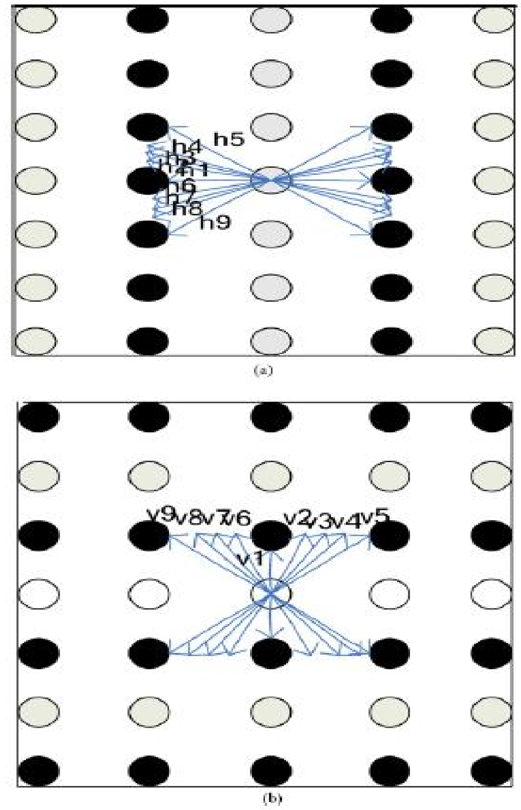


Fig. 1. Lifting Direction (a) Horizontal Lifting Direction. (b) Vertical Lifting Direction.

Direction-aware wavelet/subband-based image coding methods fall into two major categories in their ways of using and coding directional information.

1) Directional Filter and Transform: The 2-D filter bank that produces a one low-pass component image and N directional component images containing high-frequency components in a given direction [10]. Li *et al.* incorporate subband decomposition into the Ikonomopoulos' scheme [11], where each rectangular subband contains a given direction. Bamberger *et al.* propose a filter bank with critically sampled and wedge-shaped regions to describe directional information [12], which receives more attention for the virtues of maximal decimation and perfect reconstruction. In this time many new wavelet transforms have been proposed to preserve fine directional information in the wavelet domain, such as ridgelet [13], curvelet [14], directional wavelet transform [15], contourlet [16], complex wavelet [17], brushlet[18], and so on.

These directional filters and transforms provide good presentations of directional data in the frequency domain. They are extensively applied in feature extraction, image enhancement, denoising, clas- sification, and even retrieval.

2) Directional Prediction: The directional prediction in wavelet decomposition is the conflict of global transform and local features. Natural images usually contain rich orientation features. Partitioning an image into many small regions according to correlation direction may cause severe boundary effects and hurt coding efficiency. Taubman *et al.* propose a technique to resample an image before conventional subband decomposition [19].

The resampling process rotates image edges into horizontal or vertical directions so that following subband decomposition can gain accurate predictions from neighboring horizontal or vertical pixels. A similar idea on wavelet packets is also reported in [20] and [21].

An additional method for directional prediction is to separate images into two or more parts, in which pixels of one part can be directionally predicted from other parts during wavelet decomposition [22].A new technique of seamlessly integrating directional prediction in arbitrary orientation into the familiar framework of lifting-based 2-D wavelet transforms. The lifting structure developed by W. Sweldens is an efficient and popular implementation of wavelet transform, in which each finite impulse response (FIR) wavelet filter can be factored into several lifting stages [23]. A local prediction can be readily incorporated into each lifting stage because the lifting stage only involves a few neighboring pixels in the calculation of predicting and updating signals.

ADL is a general framework that allows the use of any 1-D wavelet filter, such as the popular Haar, 5/3 and 9/7 wavelets, to perform 2-D decomposition on images. The replacement of conventional rectilinear wavelet transform by ADL and the adaptive segmentation component, the other components of the proposed image-coding system resemble their counterparts of JPEG 2000.

III. A NEW ADAPTIVE DIRECTIONAL LIFTING

The ADL-based transform can overcome the difficulty of rectilinear 2-D wavelet transforms in approximating image signals of edges and textures in arbitrary directions.

A. Directional Lifting Structure

The ADL analyzes the local spatial correlations in all directions, and then chooses a direction of prediction in which the prediction error is minimal.

Suppose a 2-D signal $x(m,n)_{m,n\in z}$. Without loss of generality, we assume that this signal is first decomposed into high and low subbands by a 1-D wavelet transform in the vertical direction and then in the horizontal direction. With the technique given in [24], each 1-D wavelet transform can be factored into one or multiple lifting stages. A typical lifting stage consists of three steps: split, prediction, and update.

In the first step, all samples are split into two parts: the even polyphase samples x_e and the odd polyphase sample x_o.

$$\begin{cases} x_e(m,n) = x(m,2n) \\ x_o(m,n) = x(m,2n+1). \end{cases} \quad (1)$$

In the predicting step, the are predicted from the neighboring even polyphase samples and this odd polyphase samples located at integer positions. The Predicted residue is calculated with the following equation.

$$h(m,n) = x_o(m,n) - p_e(m,n). \quad (2)$$

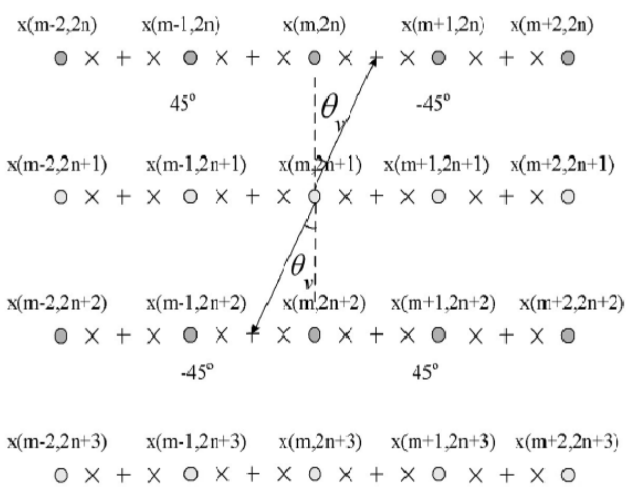
In the conventional lifting, the predictions always come from the vertical neighboring even polyphase samples. It can select the best predictions from the surrounding even polyphase samples. As shown in Fig. 2, assume that the pixels has a strong correlation at the angle θv , where the integer pixels are represented by the "O" markers, the half pixels are represented by the "×" markers. and the quarter pixels are represented by " + " the markers. Then, the predictions of $x(m,2n+1)$ come from the even polyphase samples pointed by the arrows in Figure 2. It is calculated as follows.

$$P_e(m,n)=\sum_i \alpha_i x_e(m+\mathrm{sign}(i-1)\tan\theta_v, n+i) \quad (3)$$

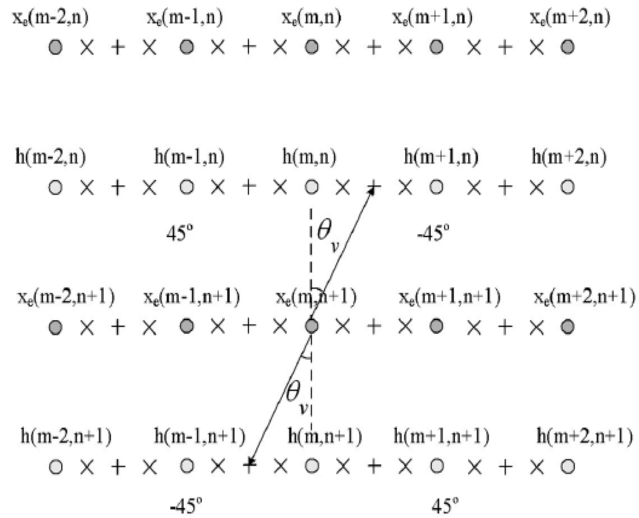
In this equation no. 3 where sin(x) is 1 for $x \geq 0$ and otherwise -1, and α_i is the weight given by filter. The conventional lifting can be viewed as the special case with $\theta v = 0$. The corresponding finite impulse response function is

$$P(z_1,z_2)=\sum_{i=a}^{b}\alpha_i z_i^{\mathrm{sign}(i-1)\tan\theta_v} z_2^{i}. \quad (4)$$

we consider the FIR wavelet filter in case only a finite number of coefficients α_i are non-zero. Assume a and b be the smallest and largest integer number of *i*, respectively. After the calculation of Equation (2), we obtain a new representation of $x(m,n)$ by replacing $x_o(m,n)$ with the predicted residue $h(m,n)$. It is equivalent to $x(m,n)$. Since the prediction is always calculated from the even polyphase samples, if the directional angle is known, the lifting can still perfectly reconstruct the odd polyphase samples with Equation (2).



(a) Prediction Process



(b) Update Process

Fig.2. Angle of the vertical transform in the Lifting (a) Prediction Process and (b) Update Process

In the updating step, the even polyphase samples are replaced with

$$l(m,n)=x_e(m,n)+u_h(m,n). \quad (5)$$

The update step of the proposed ADL scheme is performed in the same angle as that in the prediction step. We say that the ADL framework is very general, and it does not have any restriction on the update angle. We keep the prediction and update angles the same to save the side information of coding the angles. Therefore, the updating signal of the even polyphase samples is given as

$$u_h(m,n)=\sum_j \beta_j h(m+\mathrm{sign}(j)\tan\theta_v, n+j). \quad (6)$$

The corresponding finite impulse response function in domain is

$$U(z_1, z_2) = \sum_{j=c}^{d} \beta_j z_1^{\mathrm{sign}(j)\tan\theta_v} z_2^j \quad (7)$$

Where c and d *be* the smallest and largest integer number of *j*, respectively, where β_j is non-zero. Obviously, this step is trivially invertible with the known angle again.

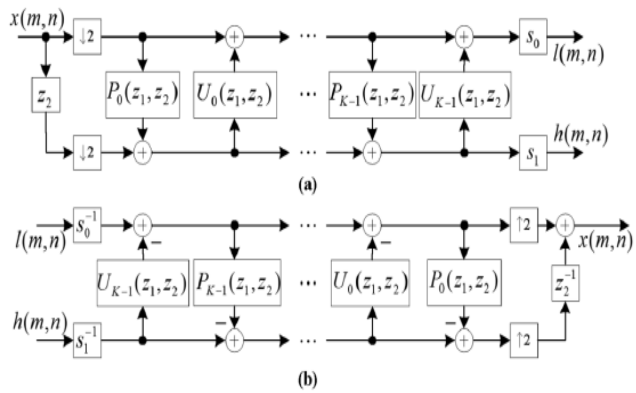


Fig.3.The Generic 1D Lifting Transform (a) Analysis Side (b) Synthesis side

In this Fig.3 present a schematic diagram of the proposed Lifting-based wavelet transform. The proposed FIR functions of the extended Haar, 5/3 and 9/7 filters are given as follows, respectively:

$$\text{Haar}: \begin{cases} P_0(z_1, z_2) = -z_1^{-\tan(\theta_v)} \\ U_0(z_1, z_2) = z_1^{\tan(\theta_v)}/2 \\ s_0 = s_1 = 1 \end{cases} \quad (8)$$

$$5/3: \begin{cases} P_0(z_1, z_2) = -\left(z_1^{-\tan(\theta_v)} + z_1^{\tan(\theta_v)} z_2\right)\Big/ 2 \\ U_0(z_1, z_2) = \left(z_1^{\tan(\theta_v)} + z_1^{-\tan(\theta_v)} z_2^{-1}\right)\Big/ 4 \\ s_0 = s_1 = 1 \end{cases} \quad (9)$$

$$9/7: \begin{cases} -1.586134\left(z_1^{-\tan(\theta_v)} + z_1^{\tan(\theta_v)} z_2\right) \\ -0.05298\left(z_1^{\tan(\theta_v)} + z_1^{-\tan(\theta_v)} z_2^{-1}\right) \\ 0.882911\left(z_1^{-\tan(\theta_v)} + z_1^{\tan(\theta_v)} z_2\right) \\ 0.443506\left(z_1^{\tan(\theta_v)} + z_1^{-\tan(\theta_v)} z_2^{-1}\right) \\ s_0 = 1.230174 \\ s_1 = 1/s_0 \end{cases} . \quad (10)$$

The conventional 2-D wavelet transform, the 2-D Lifting wavelet transform can decompose an image into multiple levels of different scales. The 2-D Lifting wavelet transform splits the low and high subbands horizontally and vertically in turn in the exactly same way as conventional wavelet transform, creating LL, LH, HL, and HH subbands in one level of decomposition. In the HL subband, only the top row of horizontal stripes contains significant amount of energy after the generalized vertical transform. The adaptive directional prediction successfully removes the statistical redundancy in all other directional patterns, which is exhibited by uniformly small prediction errors in the bottom three rows of the HL subband. The HH subband has even less amount of energy with no recognizable signal structures remaining, after the generalized vertical and horizontal transforms. In the LH subband, the energy compaction is less effective than in HL and HH subbands. So vertical stripes still remain, some high-frequency diagonal textures also exist in LH subband.

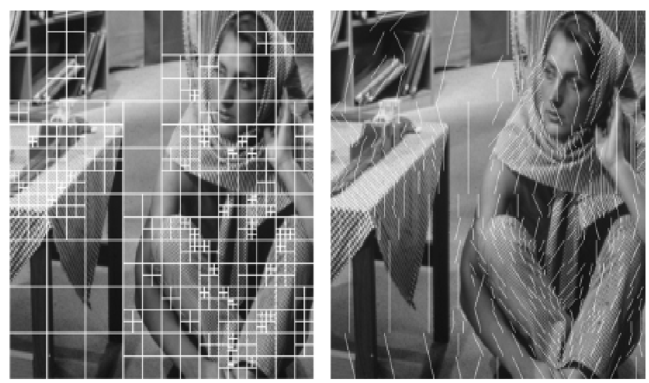


Fig.4. Partition of Barbara and the directions for each block.

B. Interpolation

In order to perform directional prediction in an arbitrary angle θv, the proposed ADL scheme needs to know the intensity values at fractional pixel locations. In other words, used in (3) and (6) are generally not integers. Hence, the interpolation of subpixels becomes an issue. The interpolation technique using (3) as an example. For perfect reconstruction, the integer pixels used to interpolate the fractional pixel at angle θv have to be even polyphase samples $x_{e(m,n)}$. It cannot use odd polyphase samples $x_{o(m,n)}$ can participate in the prediction. The interpolation can be defined as

$$x_e(m + \text{sign}(i-1)\tan(\theta_v), n+i) = \sum_k a_k x_e(m+k, n+i). \quad (11)$$

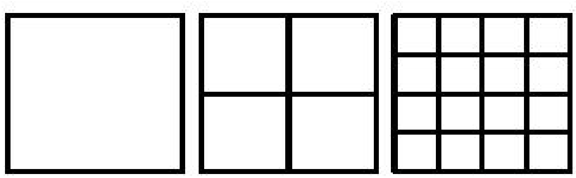
In this equation (11) the subscript k is indexes the integers around sign$(i\text{-}1)$tan(θv), and a_k is the interpolation filtering parameters. Based on (3) and then after z transform of equation (11), we have

$$z_1^{\text{sign}(i-1)\tan(\theta_v)} = \sum_k a_k z_1^k. \quad (12)$$

The parameter a_k is a finite number of non-zero coefficients. We adopt the popular since interpolation, which decide the value a_k.

C. Direction Angles Estimation

The directional angles of each sample are estimated locally at block. As shown in Fig. 5, a block can be partitioned into three modes: 16x16, 8x8 and 4x4. In the 16x16 mode, all pixels have the same directional angle. In the 4x4 mode, each block has 16 directional angles and all pixels in a 4x4 sub-block share the same angles.



16x16 8x8 4x4

Fig.5. Three partition modes for direction estimation angles.

IV. Experimental Results and Analysis

In this experiments the vertical lifting transform can be selected from [-45º,45º] with the quarter-pixel precision. In other words, the vertical lifting transform has 9 different angles. Then prediction of the horizontal lifting transform can be selected.

The proposed Lifting wavelet transform is implemented. In this the ADL performance only as objectively as possible, we simply replace the wavelet transform module of JPEG 2000 by the ADL transform and use the same bit-plane coding (quantization module).

Fig. 6. Coefficient magnitudes of (top) JPEG 2000 and (bottom) ADL after one level of decomposition.

In this experiment Table I represent the average coefficient magnitudes of the LH, HL, and HH subbands. The ADL technique has a significant advantage over the conventional wavelet transform on Barbara. This should be expected because this testing image contains strong directional textures. The reduction in average coefficient magnitude is 55.8% in the LH subband, 36% in the HL subband and 34.6% in the HH subband. On other test images the ADL technique also outperforms JPEG 2000. the LH, HL and HH subbands are scaled into the range [0, 255] in the plot.

Table I: Average Coefficient Magnitude in the LH, HL, HH Subbands.

Subbands/Method		Babara	Bike	Cafe	Foreman
	JPEG 2000	5.31	3.01	5.01	1.3
L H	ADL	2.35	2.25	4.04	0.92
	Reduction	55.8%	27.3%	19.2%	24.3%
	JPEG 2000	2.26	3.19	5.51	2.07
H L	ADL	1.44	2.39	4.4	1.43
	Reduction	36.0%	25.1%	20.1%	31.5%
	JPEG 2000	1.48	1.05	1.56	0.6
H H	ADL	0.97	0.88	1.5	0.51
	Reduction	34.6%	15.5%	4.5%	16.0%

The lifting scheme outperforms JPEG2000 up to 2dB in Barbara, 1.5dB in Foreman, 0.7dB in Bike and 0.2dB in Cafe.

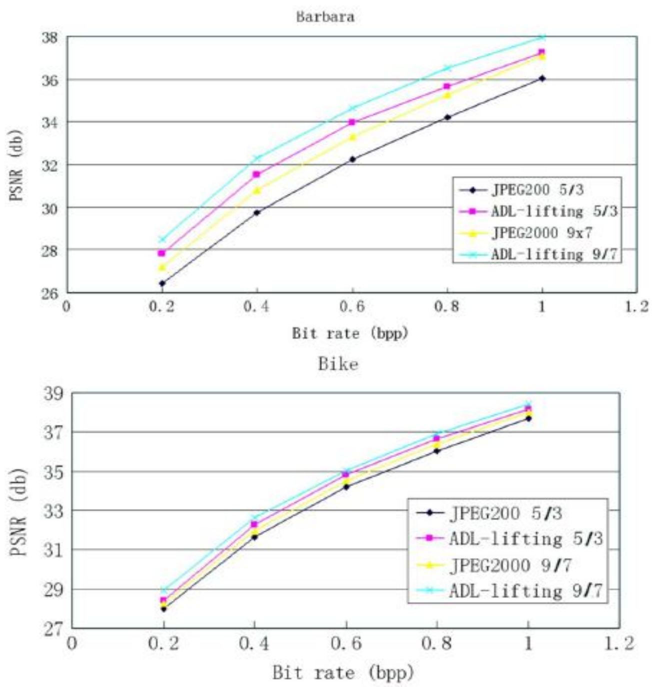


Fig.7. PSNR curves of ADL- Wavelet based code

V. Conclusions

In this paper, a new image coding method based on adaptively selecting directional lifting or normal horizontal/vertical lifting is presented. In this algorithm, image is partitioned into many blocks. For each block lifting wavelet transform or horizontal/vertical lifting should be used. Then image blocks with different directions are continuously processed, which may cause boundary effects in the block boundaries.

The proposed algorithm can reduce the computational complexity of wavelet transform, while maintaining similar compression performance in terms of PSNR. Compared to some other existing methods, our method outperforms them in terms of PSNR.

ADL lifting stage, the prediction step can be performed in the direction of the strongest pixel correlation rather than stay fixed in the horizontal or vertical direction. Even though its prediction and update operations are based on fractional pixels, the ADL wavelet transform can guarantee perfect reconstruction without imposing any constraint on the interpolation method.ADL can also efficiently approximate directional image features in local regions.

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