1—3 Block-based Layered Coding of Images Using Subband Coding

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ABSTRACT

The present block-based DCT encoder transforms images regardless of layers and then simply partitions the transformed data into a few layers, for example low and high frequency bands in JPEG. Yet, it fails to utilize the similarity of coefficients in each band. Therefore, we combine the subband coder and the block-based DCT coder in this paper. The new coding scheme enables the data to automatically be classified into several layers and increases the efficiency of transform. Various possible coding structures are investigated and the simulation results are also provided.

1. INTRODUCTION

The layered encoder of images partitions the data into several classes according to the importance. It provides various quality-level and attributes the priority in transmission to the data.

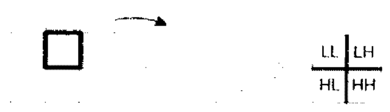
For example, the layered encoder provided by JPEG simply classifies DCT coefficients into low and high frequency bands [1]. In this method two different bands are DCT-transformed all together, but it is advantageous to DCT-transform the data belonging to each band respectively because each band has the different statistical characteristic.

On the other hand, subband coder first decomposes the data into several frequency bands and encodes the decomposed data in each frequency band which have the similar statistical characteristic. Subband coder not only encode the data by utilizing this respective statistical characteristic but also automatically classifies the data into several layers according to the importance.

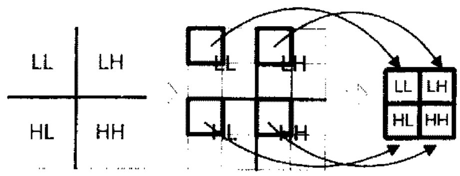
But the coding standards of still or moving pictures, such as JPEG and MPEG, process images based on block. If images are process-ed by block-based encoder, we have many advantages. For example, block-based encoder is realized by simple and parallel-processing hardware and is efficient in the statistical sense because the data, which is confined in a small region or a block, is stationary.

In this paper the new encoding structure, which combines the subband coder and the block-based coder, is proposed in order to keep two advantages. The proposed method has two possible coding structure. In Fig. 1 (a) the encoder first partitions the images into blocks and each block is decomposed by subband coder. In Fig. 1 (b) the whole image is decomposed by subband coder and each band is partitioned into blocks.

In the proposed scheme, the block of each subband is DCT-transformed, scanned by zig-zag scan order, and run-length coded like JPEG baseline. Because each decomposed subband has the different correlation coefficients, we have the different scan order and the quantizer step size for each subband in order to have lower bit rates than the present block-based coder.

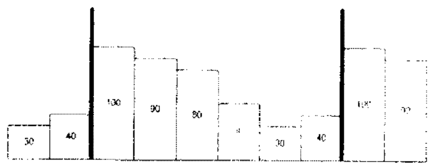


(a) subband coding after block partition

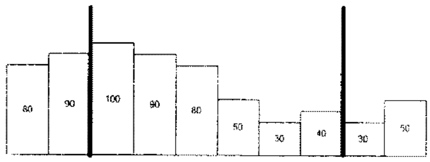


(b) block partition after subband coding

Fig. 1 The structure of encoder



(a) circular filtering (orthogonal wavelet)



(b) reflection filtering (biorthogonal wavelet)

Fig. 2 Filtering and type of wavelet

2. SUBBAND CODING

Subband coding method itself is similar to the method of successive approximation and automatically classifies the data into several layers. Recently, the subband filters, which have the 'regularity' [2] in spatial domain, are proposed as the name of wavelet filters. There are two types of wavelet filters, orthogonal and biorthogonal wavelet filter, according to the orthogonality among filter banks.

First, orthogonal wavelet has analysis and synthesis filter banks which are originated from same wavelet function and the impulse responses of filter banks have the relation given by (1) where h_0 is low-pass and h_1 is high-pass filter. In orthogonal wavelet the orthogonality cannot be consistent with FIR linear phase, and orthogonal and FIR linear phase wavelet has the only trivial case, Haar basis [2]. Generally, orthogonal wavelet filters, which are originated from the significant wavelet functions in the sense of approximation, are IIR and not suitable to apply to image coding, but Daubechies proposed orthogonal bases of compactly supported FIR wavelet filters [3].

The filters proposed by Daubechies are not linear phase and can not have symmetric impulse response. So, they are convolved with image signal by circular filtering, just like Fig. 2 (a). Circular filtering method extrapolates the signal at the boundary on the assumption of the periodicity of signal, and so has the problem that coding efficiency is reduced by the increase of high frequency components because there is a discontinuity at the boundary. Because most encoders quantize the high frequency components coarsely, there are blocking artifacts at the filtering boundary which is mostly composed of high frequency components.

Second, biorthogonal wavelet has the different analysis and synthesis filter banks, each of which is originated from a different wavelet function. In this case low-pass and high-pass filter in the same banks are not orthogonal mutually but low-pass in analysis banks and high-pass in synthesis banks are orthogonal, vice versa. So, the impulse responses of filter banks have the relation given by (2) where h is analysis bank and g is synthesis bank.

Biorthogonal wavelet can be designed for their impulse response to be symmetric under the constraint of the perfect reconstruction. Many papers designed biorthogonal filters suitable for their applications and provided the coefficients of impulse response [2], [4].

Because biorthogonal wavelet is designed for their impulse response to be symmetric, they are convolved with image signal by reflection filtering, just like Fig. 2 (b) suggested in [5]. Only symmetric filter can be convolved by reflection filtering because the symmetry is conserved after filtering when the filter is symmetric.

As we know from Fig. 2 (b), there is no severe discontinuity at the filtering boundary and the coding efficiency is higher than that of circular filtering. But, biorthogonal wavelet does not conserve the energy and the total distortion is not the direct sum of the distortions of each subband. Therefore it is difficult to optimize the quantizer and in this paper we design the quantizer assuming that the total distortion is the direct sum of the distortions of each subband.

3. BLOCK-BASED ENCODER USING SUBBAND CODING

In this paper we proposed the new coding structure by combining the subband coding and block-based coding. Block-based encoder using subband coding has two possible structure illustrated by Fig. 1.

First, in Fig. 1 (a) the encoder first partitions the images into blocks and each block is decomposed by subband coder. In this structure the convolution is performed in a small block and a short-length filter is preferable.

And it has the filtering boundary at each block boundary while ordinary subband coding has the filtering boundary at the image boundary. If orthogonal wavelet is used and circular convolution is performed, the performance of this structure is degraded seriously because of blocking artifacts. So, biorthogonal wavelet, which has no serious discontinuity at the boundary, is preferable to orthogonal wavelet in this structure.

This structure preserves the advantages of block-based coding to some degree, such as simple and parallel-processing hardware and statistical locality. But there is still blocking artifacts because the last step of reconstruction is block-by-block wavelet synthesis and blocking artifacts described above can be more serious than that of the block-based coder when orthogonal wavelet

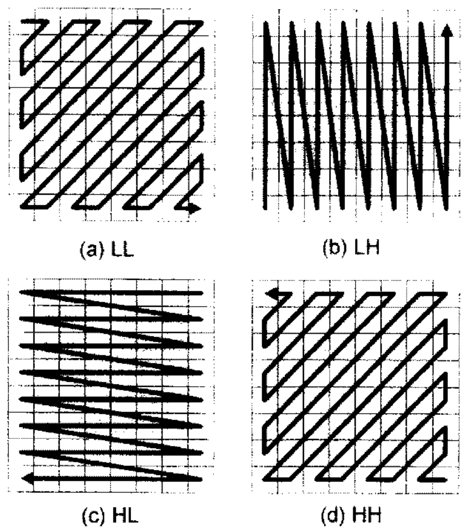


Fig. 3 Scanning order of each band

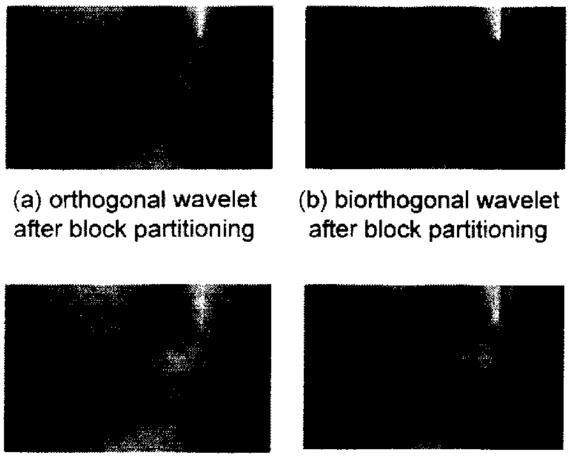
is applied to this structure.

Second, in Fig. 1 (b) the whole image is decomposed by subband coder and each band is partitioned into blocks. In contrast with the first structure it has the filtering boundary at the image boundary. So, the performance of this structure is not degraded seriously by using orthogonal wavelet and is dependent on the performance of the filter itself.

Blocking artifacts is reduced because the last step of reconstruction is wavelet synthesis of the whole image, and the second structure is subjectively superior to the first structure because of less blocking artifacts when two structures have the same PSNR.

4. QUANTIZATION AND ENTROPY CODING

Now partitioned blocks is classified into four class, LL (horizontal low, vertical low), LH, HL, and HH. Each class or each subband has the different spectral characteristic and the spatial correlation and we must design the different quantizer for each band to use this fact. Just like JPEG baseline lossy encoder, the post-transform encoder was composed of quantization, scanning, run-length coding, and Huffman Coding. The quantizer is uniform and has the



(a) orthogonal wavelet after block partitioning
(b) biorthogonal wavelet after block partitioning
(c) block partitioning after orthogonal wavelet
(d) block partitioning after biorthogonal wavelet

Fig. 4 Reconstructed images by 4 encoders

deadzone of double step size to enhance the performance of run-length coding.

LL is coded like JPEG baseline because it is the approximation of a original image. In other words LL is DCT-transformed by 8×8 bock, quantized by the quantization matrix provided JPEG, reordered by zig-zag scanning, run-length coded and Huffman coded.

The other subbands are quantized by fixed step size and the scanning order of them is modified. LH has the large horizontal correlation coefficient and so the DCT coefficients of LH is reordered like Fig 3 (b). In the same manner the DCT coefficient of HL is reordered like Fig. 3 (c) and that of HH is reordered like Fig. 3 (d).

Then the quantization step size must be determined to minimize the distortion under the constraint of given bit rate. For the finite sets of the quantization factor of LL and the quantization step size of the other bands, we optimize the quantizer by the rate-distortion bisection algorithm.

5. SIMULATION RESULTS

The 8-tap filter provided Daubechies is selected among orthogonal filters and the filter provided Antonini [4] is selected among biorthogonal filters in this simulation. To

Table 1 Quantization step size and rate-distortion percentage at 0.5 bpp

type	band	step size	bit rate (%)	distortion(%)	
1	LL	17/8	83.7	31.86 dB	52.8
	LH	12	4.1		18.1
	HL	11	11.3		22.0
	HH	12	0.9		6.4
2	LL	12/8	80.5	34.42 dB	46.5
	LH	8	4.4		19.7
	HL	7	13.9		23.4
	HH	8	1.1		10.4
3	LL	12/8	84.6	34.63 dB	46.7
	LH	9	3.3		18.2
	HL	8	10.9		24.7
	HH	9	1.1		10.5
4	LL	11/8	84.8	35.10 dB	48.9
	LH	8	3.0		17.4
	HL	7	11.1		23.2
	HH	8	1.0		10.5

compare the performance of filters fairly, we use filters of the same number of taps (the biorthogonal filter has 9 taps in analysis and 7 taps in synthesis). If two structure in Fig. 1 are applied to each filter, there are four possible encoders. Type-1 is classified by orthogonal filter and type-2 by biorthogonal filter after block partitioning. Type-3 is classified by orthogonal filter and type-4 by biorthogonal filter before block partitioning.

We optimize the Huffman table and do not confine the huffman code length within 16 bit. But for simple hardware, it is desirable that the fixed huffman table to be obtained by training sequence is used. Also the quantizer is optimized over the finite sets and is desirable for simplicity to fix up.

Table 1 shows the optimized quantization step size and the rate and distortion percentage for each band at 0.5 bpp.

The magnified images, which is reconstructed at 0.1 bpp by 4 type encoders, are presented in Fig. 4. In the case of type-1 there are serious blocking artifacts at the block boundary in Fig 4. (a) because of discontinuity made by circular filtering.

respectively.

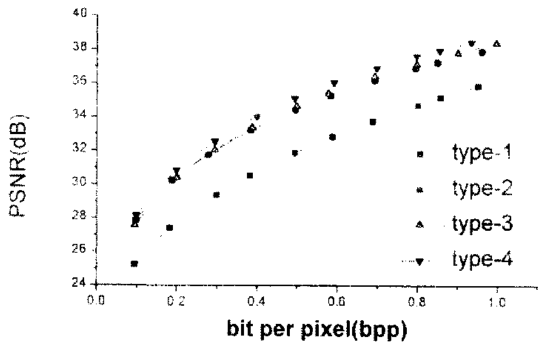


Fig. 5 Rate-distortion curve of the new coders

Blocking artifact is reduced in Fig 4. (c) and (d) because the last step in reconstruction is synthesis filtering in the case of type-3 and type-4.

Fig. 5 shows the rate-distortion curves of 4 type encoders. Type-1 is inferior to the other types by 3~4 dB because of blocking artifacts. The other types show the similar performance but type-4 shows the best performance, having greater PSNR by about 0.5 dB

6. CONCLUSION

The new encoder, which combines the block-based coder and the subband coder, is proposed in this paper. Type-4 shows the best performance but loses the advantages of block-based coder because it classifies the whole image by subband coding. Type-2 is slightly inferior to type-4 in performance, but it keeps the advantages of block-based coding because of the block-by-block subband decomposition. And type-2 is easy to implement by inserting the filter before DCT because block-based subband filtering can be done in DCT domain.

If the proposed encoder is used, we can transform the low frequency components and the high frequency components separately. Therefore the data is automatically layered into several classes and the coding gain is increased because the data, which share the similar statistical characteristic, are coded

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