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Image Compression Using Hybrid methods

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Abstract

This paper aims to investigate the performance of a suggested wavelet based image compression system. The scheme of the proposed system utilizes 9/7 biorthogonal wavelet transforms to decompose the image signal, then uses DCT and quadtree coding to compress the approximate and detail subbands, respectively. A hierarchal quantization scheme was applied to reduce the number of bits required to encode the wavelet coefficients. According to their visual importance, quadtree encoding was utilized as a further step to encode the quantized wavelet coefficients. The test results indicate that the proposed compression scheme shows good performance aspects.

Keywords: Image compression, Wavelet transform, DCT, Quadtree coding.

Introduction

Compression is the process of eliminating or saving in a short form the data that is duplicated or that have no value. Most image file formats use compression because image files tend to be large and consume large amounts of disk space and transmission time over networks.

Over the past few years, a variety of powerful and sophisticated wavelet-based schemes for image compression, have been developed and implemented. Because of the many advantages, the top contenders in the upcoming JPEG-2000 standard [1] are all wavelet-based compression algorithms. It is a replacement for the JPEG algorithm, developed by the ISO JPEG group in 2000. It provides for lossy and lossless compression, and uses wavelet compres- sion to achieve higher compression rates with a lower corresponding reduction in image quality [2].

There are many features that are present in Discrete Wavelet Transform (DWT) but not in Discrete Cosine Transform (DCT) that make the use of DWT desirable for image compression [3]:

First, an unconditional basis causes the size of the expansion coefficients to drop off with j and k for many signals. Since wavelet expansion also allows a more accurate local description and separation of signal characteristics, the DWT is very efficient for compression.

Second, an infinity of different wavelets creates a flexibility to design wavelets to fit individual applications.

Proposed System Layout

Figure (1) presents the layout of the proposed compression system, it consists of the following steps:

1. In the first step, the image data is decomposed into (RGB) color components, then they transformed to another color domain (i.e., YUV Color model).
2. For Y-component encoding:
   a. The Y band is transformed using Biorthogonal Wavelet transform (tap 9/7).
   b. Apply the hierarchal quantization.
   c. Perform block coding (i.e., the quadtree encoding) on each sub band separately.

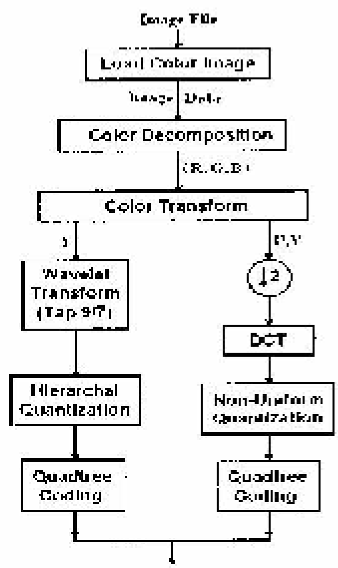

Fig. (1) Block diagrams of the proposed system

3. For Y-component encoding:
   a. The Y band is transformed using Biorthogonal Wavelet transform (tap 9/7).
   b. Apply the hierarchal quantization.
   c. Perform block coding (i.e., the quad tree encoding) on each sub band separately.

4. For (U,V) Encoding:
   a. Down sample the U and V bands using the average method. This is due to the fact that components U and V hold 10% of the whole image information, and the reduction in their spatial resolution causes insignificant subjective distortions in the color image.
   b. Then, the down sampled U and V bands are transformed by using discrete cosine transform (DCT).
   c. Use the ***non-uniform quantization*** to quantize the resulted output from the DCT.
   d. ***Down sample*** in order to minimize number of bits needed to store the file.
   e. Use the ***quadtree encoding*** method to store the array, and then save the result in the file.

The Color Transform

It is a one-to-one transformation, applied to the input (R,G,B) image data. The transformation output is an image representation which is more amenable to efficient compression than the raw data image [1].

The color transform is utilized in image compression schemes, because it helpful to reduce the spectral redundancy, also it exploits some of the characteristics of the human vision system to improve the compression performance.

Many compression standards convert (R,G,B) bands to (Y,U,V) bands. In this kind of color model; more than 90% of the image information are concentrated into the band (Y), the remaining information will be in the other two bands.

After applying the color transform, the fidelity criteria; the mean square error (MSE) and peak signal to noise ratio (PSNR) were determined to assess the overall error caused by the transformation. The values of both criteria are (MSE=0.0139; PSNR=66.7 dB), when the *"horses"* image, shown in Figure (2a), was used.

Down-Sampling

The goal of this step is to reduce the U & V bands sizes to quarter (25%) of their original sizes, and it is done by replacing each four pixels by one pixel, whose value is the average of the four pixels.

In the image decoding phase, the retrieved reduced U & V subbands are enlarged 4 times; this enlargement is done by duplicating each pixel in the image four times.

The values of MSE and PSNR due to color transform and down sampling processes were determined and they found 2.259, 44.592, respectively.

Discrete Cosine Transform (DCT)

JPEG compression standard uses DCT to compress the image data, after partitioning it into blocks (8x8 pixels). This compression scheme discards the trivial (small) high frequency information in order to achieve compression. The more you compress the image, the more frequency information is discarded. Radical compression leaves only the most important information, which conveys the essentials of the image, but looses much of the subtlety that makes a pleasing continuous tone image [5].

The error due to color transform and DCT application on the U and V bands is described by the measures MSE and PSNR, their determined values are found 0.501, 51.04 dB, respectively.

DCT Coefficients Quantization

Quantization is the process of reducing the number of bits needed to represent the transformed coefficients by reducing the precision of those values. Since this process is a many-to-one mapping, it is a lossy process and is the main source of compression in the encoding path [6].

A quantizer can be specified by its input partitions and output levels (also called reproduction points). If the input range is divided into levels of equal spacing, then the quantizer is termed as a **uniform** quantizer, and if not, it is termed as a **non-uniform** quantizer.

In this work, the uniform quantization was applied, the quantization step (Q) of the DCT coefficient, whose indices are i and j, is determined by the following equation:

$$Q = \frac{\alpha r(i+j)}{s}$$

where, α = 1 or 2,
r = [0.1 , ..., 5], and
s = 2, 4, 6, or 8

The MSR and PSNR values, listed in table (1), were determined after applying the color transform, down sampling, DCT, and quantization with different α and r values.

Table (1) DCT quantization effects

α	r	MSR	PSNR (dB)
0.5	1	2.681	43.85
1	1	2.689	43.84
2	1	2.834	43.61
3	1	3.139	43.16
4	1	3.510	42.68
5	1	4.337	41.76
0.5	2	2.768	43.72
1	2	2.954	43.43
2	2	3.720	42.43
3	2	5.997	40.35
4	2	8.986	38.60
5	2	10.938	37.74

Biorthogonal Wavelet Transform

Wavelet transform transfers, iteratively, one signal into two or more filtered and decimated signals corresponding to different frequency subbands. A group of transforms coefficients resulting from the same sequence of low pass and high pass filtering operations, both horizontally and vertically, are called subbands. The number of decompositions performed on original image to obtain subbands is called subband decomposition level.

After applying the color transform, the produced Y-band was decomposed by using the biorthogonal 9/7 wavelet transform tree hierarchal, see figure 2. The effect of the number of transform passes (1, 2, and 3) on the MSE and PSNR were determined, and the results tabulated in table (2).

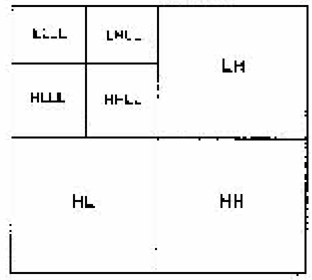

Fig. (2) Wavelet Subbands

Table (2) The effect of wavelet transform

No. of passes	MSR	PSNR (dB)
1	3.941	45.25
2	4.635	41.47
3	6.633	39.91

Wavelet Coefficients Quantization

The uniform quantizer can be easily specified by its lower bound and step size. Also, the implementation of uniform quantization is easier than non-uniform quantization. In this work, a hierarchal quantization is applied on all the detailed sub-bands.

The MSE and PSNR were determined after applying the color transform, down sampling, DCT followed by quantization (with different α and rate) applied upon U and V subbands, and wavelet (tap 9/7) followed by quantization applied on Y subband. The results are listed in table (3). The best compression results for U and V are obtained when 11 bits aee used to encode both U and V.

Table (3) The compression results of the Y-band

LLLL	LLLH	LLHL	LLHH	LLH	LHL	LHH	LH	HL	HH	No of passes	r	Rate	MSE	PSNR
1	1	1	1	1	1	1	16	16	64	1	1	1	12.453	38.89
1	1	1	1	1	1	1	16	16	64	2	1	1	15.419	36.25
1	1	1	1	1	1	1	16	16	64	3	1	1	17.441	35.72
1	1	1	1	1	1	1	16	16	64	3	5	1	21.550	34.84
1	1	1	1	1	1	1	16	32	64	3	5	2	27.735	33.7
2	2	2	2	2	2	2	16	16	64	3	5	2	36.950	31.06
1	1	1	1	1	1	1	32	32	64	3	5	2	39.964	32.31
1	1	1	1	1	1	1	64	64	128	3	5	2	56.000	30.65
2	2	2	2	2	2	2	64	64	128	3	5	2	57.070	30.57
1	1	1	1	1	1	1	64	64	128	3	5	1	49.849	31.15
2	2	2	2	2	2	2	16	16	64	3	4	1	50.930	31.05
4	4	4	4	4	4	4	16	16	128	3	5	2	62.505	30.17
4	8	8	16	8	8	16	64	64	128	3	[illegible]	[illegible]	61.820	30.22
2	8	8	16	8	8	16	64	64	128	3	[illegible]	[illegible]	58.747	30.44
[illegible]	16	16	64	16	16	96	16	16	16	3	[illegible]	[illegible]	65.617	29.55
[illegible]	16	16	32	16	16	72	16	16	32	3	[illegible]	[illegible]	55.990	30.68
4	8	8	16	16	16	32	32	32	64	3	[illegible]	[illegible]	55.282	30.70

Table (4) lists the final compression results after combining the compression results of the Y-band (after 3 passes), with those for U and V. As shown in the table, the parameters listed in the raw above last raw seem to be better to be adopted, where the number of bits needed to be used to encode the U and V bands are 8 bits, and the number of bits needed to store the LLLL subband is 8 bits.

The numbers of bits needed to be used to store the compressed file are summarized in table (5).

Table (5) The suitable number of bits

Subband	number of bits
HH	0 (omitted)
LH	2
HL	2
LHH	5
LLH	5
LHL	6
LLHH	7
LLLH	5
LLHL	6
LLLL	6

Quadtree Encoding

Quadtree encoder has adaptive nature and, where the number of necessary computations depends on the image details. Consider an image that is 256x256 in size and each pixel is one of 256 gray levels. The image is partitioned into non-overlapped sub-square blocks. Each block may be broken up into four equal-sized sub-squares when it has some sort of details [7]. This process repeated, recursively, starting from the whole image and continuing until reaching the smallest block size (i.e., 2x2 square) is reached.

The quatree encoding method is used to store the resulted detailed subbands of the Y-band. Table (6) lists the number of bytes needed to represent each detail subband.

Table (6) Number of bytes required to encode each part of figure 3.a.

Y-band	HH	33 byte
	HL	68 byte
	LH	62 byte
	LL	6022 byte
U-band		621 byte
V-band		620 byte

So, a compressed file with size 7425 (i.e., 7KB) byte was obtained, while the original file size is 192KB (compression ratio (CR) = 1:28).

Figure (3) shows some samples of the compression results.

Table (7) shows the original image size, PSNR, and the CR for figures (3.a), (3.c), and (3.e).

Original image	Original size	PSNR	Resulted size	CR
Fig. (3.a)	192 KB	30.033	7.2 KB	1:27
Fig. (3.c)	192 KB	32.4306	6.8 KB	1:28
Fig. (3.e)	192 KB	32.4033	6.2 KB	1:30

Table (4) The overall compression results

LLLL	LLLH	LLHL	LLHH	LLH	LHL	LHH	LH	HL	HH	α	Rate	step	No. of bits needed for U &V	MSE	PSNR
4	8	8	16	16	16	32	32	32	64	5	2	1	11	65.40	29.97
4	8	8	16	16	16	32	32	32	64	4	2	1	11	67.59	30.10
4	8	8	16	16	16	32	32	32	64	4	2	2	10	77.89	29.50
4	8	8	16	16	16	32	32	32	64	4	2	8	8	93.52	28.42
4	8	8	16	16	16	32	32	32	64	2	2	8	8	81.67	29.0[illegible]
4	8	8	16	16	16	32	32	32	64	[illegible]	1	8	9	71.03	29.61
4	8	8	16	16	15	32	32	32	64	.3	1	5	9	69.31	29.72
4	8	8	16	16	16	32	32	32	64	1	2	8	8	74.03	29.44
4	8	8	16	16	16	32	32	32	64	0.5	2	4	8	69.83	29.69
4	8	8	16	16	16	32	32	32	64	0.1	2	8	8	63.78	30.08
4	8	8	16	16	16	32	32	32	64	0.1	1	8	9	58.54	30.46
4	8	8	16	16	16	32	32	32	64	0.15	2	8	8	65.56	29.97
4	8	8	16	16	16	32	32	32	64	0.15	2	6	8	60.98	30.28
2	8	8	16	16	16	32	48	48	64	0.15	2	6	8	67.89	29.81
2	4	4	8	16	16	32	48	48	64	0.15	2	6	8	63.08	30.13
2	4	4	8	8	8	16	64	64	128	0.15	2	6	8	61.43	30.25
2	4	4	8	8	8	16	64	64	128	0.15	2	6	8	64.51	30.03

a. Original b. Reconstructed

c. Original d. Reconstructed

e. Original f. Reconstructed

Fig. (3) Samples of compression Results

Conclusions

The test results indicate that the proposed image compression system works in efficient ways. The use of DCT to encode the decimated U and V bands is enough to compress the U and V components without making significant subjective distortion in the chromaticity appearance. The use of wavelet to encode the data of Y-band is necessary to efficiently encode any possible high details may appear in this band.

Also, the quadtree encoder is very useful to improve the compression performance of the Y-band. This enhancement is due to sparse nature of the quantized detail subbands.

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