IMAGE COMPRESSION BASED ON BIORTHOGONAL WAVELET TRANSFORM

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Abstract

A common approach to the color image compression was started by transform the red, green, and blue or (RGB) color model to a desire color model, then applying compression techniques, and finally retransform the results into RGB model. In this paper, a low complexity and efficient coding scheme based on Biorthogonal tab3/5 wavelet filter is proposed. The proposed system consists of the color transform YC_bC_r, followed by Wavelet (Tab3/5) transform, uniform quantization using Pyramid Quantization, modified Bit map Slicing coding method, and finally Huffman coding to produce the final bit stream. The efficiency performance of the suggested image encoding methods has been evaluated by making comparisons between them and corresponding compression results obtained by applying the compression standard JPEG and JPEG2000.

Key Words: Image compression, Biorthogonal tab3/5 wavelet filter, Scalar Quantization, Bit planning, Lossless Coding.

Introduction

In a digital true- color images, each color component is quantized with 8 bits, and so a color is specified with 24 bits. As a result, there are 2^{24} possible colors for the image. Furthermore, a color image usually contains a lot of data redundancy and requires a large amount of storage space. In order to lower the transmission and storage cost, image compression is desired [1]. Most color images are recorded in RGB model, which is the most well known color model. However, RGB model is not suited for image processing purpose. For compression, a luminance-chrominance representation is considered superior to the RGB representation. Therefore, RGB images are transformed to one of the luminance-chrominance models, performing the compression process, and then transform back to RGB mode. In this paper we proposed compression scheme based on Biorthogonal tab3/5 wavelet filter. The most commonly used implementation of the discrete wavelet transform (*DWT*) is based on *MALLAT's* pyramid algorithm. It consists of recursive application of the low-pass/high-pass one-dimensional filter bank successively along the horizontal and vertical directions of the image. The low-pass filter provides the smooth approximation coefficients while the high-pass filter is used to extract the detail coefficients at a given resolution. The DWT gives us three parts of multiresolution representation (MRR) and one part of multiresolution approximation (MRA) [2]. It is similar to hierarchical sub-band system, where the sub-bands are logarithmically spaced in frequency. The sub-bands labeled LH1, HL1, and HH1 of MRR represent the finest scale wavelet coefficients. To obtain the next coarser scale of wavelet coefficients, the sub-band LL1 (that is MRA) is further decomposed and critically sub-sampled. Wavelet compression is not good for all kinds of data, transient pixel characteristics mean good wavelet compression, while smooth and/or periodic pixels are better compressed by other methods. Shen [3] proposed a wavelet based color image coding algorithm, where data rate scalability was achieved by using an embedded coding scheme. It was useful for video applications. A useful demonstrations of the JPEG2000 standardization process was provided by Skodras[4]. Pearlman et.al. [5], have proposed an embedded, block-based, image wavelet transform coding algorithm of low complexity. Extensive comparisons with SPIHT and JPEG2000 show that this proposed algorithm was highly competitive in term of compression efficiency. An embedded block-based image wavelet transform coding algorithm of low complexity has been proposed by *Tang* [6]. This block is called 3D-SPECK that provides progressive transmission. The results show that this algorithm was better than JPEG2000 in compression efficiency. Sudhakar et. al., [7], presented very rich information about methods of wavelet coefficients encoding algorithms. The main objective of this work is to establish a simple and efficient image compression scheme. The established scheme should has low complexity, high performance (low bit rate, high image quality), and progressive. In this work the concern was mainly focused on the traditional relation between the compression ratio (achieved by the wavelet transform), reconstructed image quality and the rate of the control parameters on this relation. Different standard images have been used as test images, especially these that have high textural regions, because the core of this research work is dedicated to apply an adaptive coding scheme on the very busy regions in the image.

Biorthogonal Tab3/5 filter

The LeGall 5/3 (also called Tab3/5 because the low-pass filter length is 5 and the length for high pass filter is 3) and Daubechies 9/7 (also called Tab7/9 because the filters lengths are 9 and 7 for low and high pass filters, respectively) have risen to special prominence because they were selected to be the kernel transform in JPEG2000 standard [8]. Biorthogonal wavelet decompositions are efficient for lossy and near lossless image compression, hence they are used in ISO JPEG2000 standard [9]. In most of the cases, the filters used in wavelet transforms have floating point coefficients. Since the input images have integer entries, the filter output no longer consists of integers and losses will result due to rounding. For lossless coding it is necessary to make a reversible mapping between the input integer image and its integer wavelet representation. *Odegard and Burrus*, showed that an integer version of every wavelet transform employing finite filters can be built with a finite number of lifting steps [10].

In this paper, the implementation of Tab3/5 filter using lifting-scheme implementation was adopted [11]. The basic idea behind lifting is that it provides a simple relationship between all multi resolution analyses that share the same low pass filter or high pass filter. The low pass filter gives the coefficients of the refinement relation, which entirely determines the scaling function [12].

In order to handle filtering at image boundaries, symmetric extension is used. Symmetric extension adds a mirror pixel (s) of the pixel (s) to the outside of the signal boundaries so that large errors are not introduced at the boundaries. All the approximation coefficients have been losslessly coded by using DPCM followed by applying S_Shift coding.

Suggested Compression Scheme

The operations of the suggested image compression scheme are started by applying a suitable color transform on the input colored image, as a second step the wavelet transform will be applied on the luminance and the two chrominance sub-bands. Then, some resampling processes are performed on the chrominance components. After resampling stage the transform coefficients are quantized. Some quantized coefficients are selected in adaptive way, this could be done by using improved bit-plane slicing method, and finally an entropy coding method is applied on the output of the slicing method. The block diagram of this scheme was shown in Fig. (1).

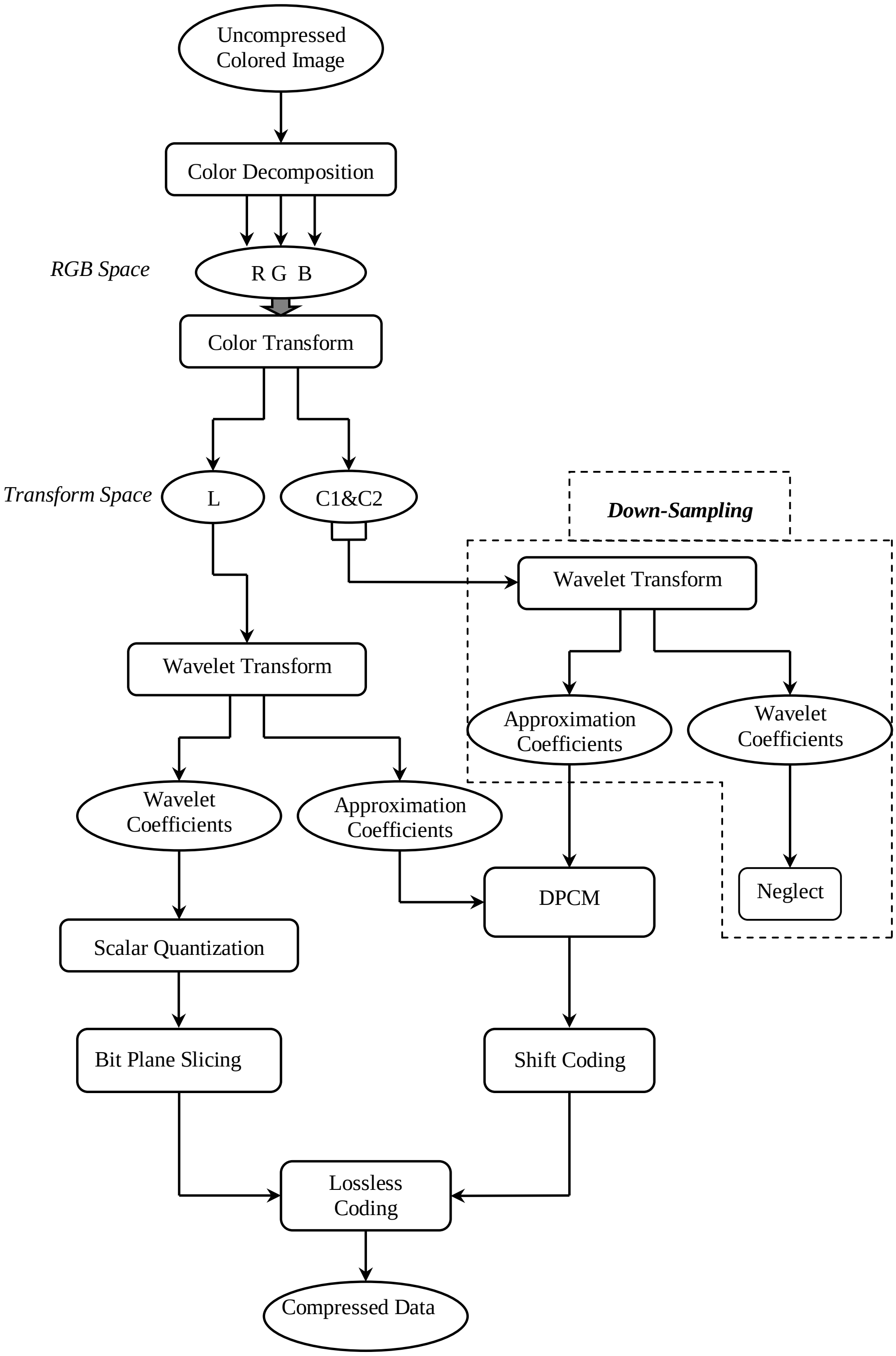

Fig. (1) : The Block Diagram of the Proposed Image Compression Scheme

Scalar Quantization

The typical way to handle floating-point data is to do scalar quantization. This approach allows some hierarchal coding techniques to be used on the quantized data, but may be unacceptable due to the irreversible data loss [13]. The quantizer is a function whose set of output values are discrete and usually finite. Obviously, this is a process of approximation and a good quantizer is one, which represents the original signal with minimum loss or distortion [14]

There are many effective ways of determining the quantizer step size. In the current research work an adaptive and simple quantization method was adopted, where the quantizer step size is changed for each wavelet level (Pass) by using the relation:

$$\beta = \beta \times \alpha^{i-1}, \qquad (1)$$

where β is the quantizer step used to quantize the coefficients of the wavelet (high pass) subbands belong to the first level (i=1), and α is the attenuation parameter (such that $\alpha<1$), i the level (pass) number. The reason behind making $\alpha<1$, is that the importance of wavelet coefficients increase with increase of subband level, so the big change in the values of wavelet coefficients belong to high level subbands will affect the image quality. The experimental results confirm this fact.

Bit-Planes Partitioning

Fig. (2) shows the bit slicing\ layering method. There are some important properties, they are:

1. The wavelet subbands contents can be partitioned into a bit base layer (most significant, MS) and enhancement layers (least significant, LS). Each enhancement layer improves the fidelity of the reconstructed image.
2. The bit stream can be truncated to yield a smaller compressed image at lower fidelity.
3. The lowest sub-bands (i.e., sub-bands labeled 3, 4, 5 and 6) can be transmitted first to yield a smaller image with high fidelity.
4. Successive sub-bands can be transmitted to yield larger and larger images.

Suppose the k^{th} detail subband, and $C_{i,j}$ is a $(i,j)^{th}$ wavelet coefficient in the k^{th} subband block k at position (i,j). Divide $C_{i,j}$ into sign $S_{i,j}(=\text{sign}(C_{i,j}))$ and magnitude $M_{i,j}(=|C_{i,j}|)$. Quantize the magnitude to $(Q_{i,j}=M_{i,j}/\beta)$, . For example, if $C_{i,j}= -40$, and $\beta=20\rightarrow S_{i,j}=0$ (0 for negative sign and 1 for positive sign) and $Q_{i,j}=2$.

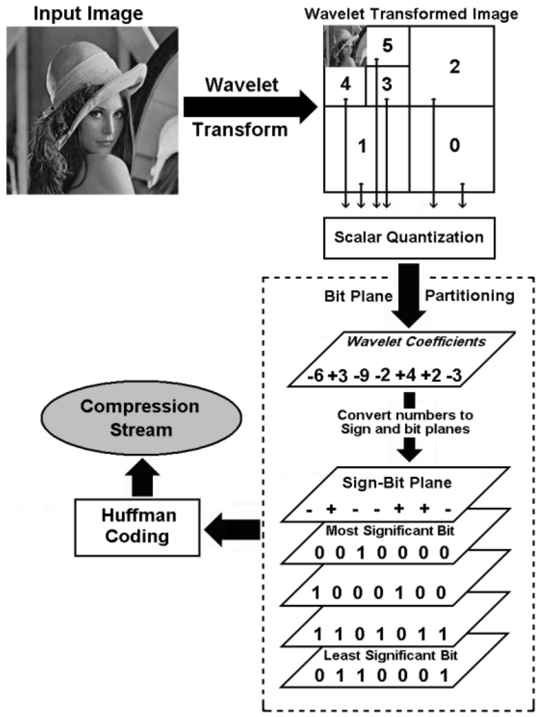

Fig. (2) : The bit slicing method

Convert $Q_{i,j}$ to its bits, and register each bit in the associated bit-planes. The image "Lena" shown in Fig. (2) is transformed using wavelet biorthogonal tab3/5 filter. The number of passes is taken 2, and k=3, β =20. It is clear that the most significant bit-planes become zero/empty (i.e., 4^{th}, 5^{th}, 6^{th} and 7^{th} bit plane), while the least significant bit-planes (i.e., 0^{th}, 1^{st}, 2^{nd} and 3^{rd} bit plane) will be less busy than before quantization. This important property will achieve high compression ratio with best image quality.

Run-Length Encoding

The most significant bitmap layers are, mostly, sparse matrices. So, to encode the contents of such bit slice a modified run length method was implemented. The out put of the modified run length consist of pairs of numbers (r, v),where r is called zero count, it is the number of subsequent zero's that collected during the scan, this count is reset after any non-zero coefficient instance. The value of v indicates to the value of number once coming after the sequence of zeros.

7. Lossless Huffman Coding

This is the final step in the suggested compression scheme, where the output bit streams (produced in bit-slicing stage) will entropy coded. Many references introduce the basic idea of Huffman coding, thus in this paper the implementation of Huffman coding is based on the frequency of occurrence of each data item (pixel in images) [15]. The principle is to use a short codeword (lower number of bits) to encode the data that occurs more frequently. Codewords are stored in a codebook, which may be constructed for each image or a set of images. In all cases the codebook plus encoded data must be transmitted to enable decoding.

Results and Discussion

The proposed method was applied on Lena and Jadriya colored images, which have 24b/p, and they size are 512×512 pixels. The performance of the suggested image encoding methods has been evaluated by making comparisons between them and the corresponding compression results obtained by applying the compression standard JPEG and JPEG2000.The comparison results of the tested images are shown in Tables (1-4). Many compression control parameters were introduced in the proposed compression schemes. The most important involved control parameters are listed below (in descending order according to its importance) and some conclusions about each are given:

a- Quantization step (s): the large changes in **s** value lead to large changes in CR.

b- Number of wavelet passes (np): the small changes in np value lead to large changes in CR. The values less than or equal to 2 are useful for applications that require lossless compression.

c- Quantization step attenuation parameter (a): very small changes in (a) values (i.e., about 0.1) lead to large changes in CR value. The best value for lossy compression is found a = 0.6.

d- Threshold boundary condition parameter (h): the value of this parameter greatly effects the decision whether the partitioned blocks of the bit-plane are considered empty (even it is not actually empty) or not. The optimal value is h=1 (i.e., if there is one element has a value equal to 1 while all other elements have zeros values. Then, consider the block empty and send 0 bit to the compression stream. The value of h depends on the image type (i.e., for busy images high h values is preferred).

e- HH_1 sub-band wavelet coefficients suppression factor (t): from the test results, shown in previous tables, the best (t) value that give so encouraging compression performance (i.e., highest CR with lowest rate distortion) is t = 0.25.

f- The sampling factor (ϕ): is the sampling factor, at which the bands (C_bC_r) are down sampled. For luminance component no down sample have been implemented. For up-sampling the method bi-linear interpolation bad been adopted

The results of the proposed scheme are encouraging taking into consideration its low complexity in comparison with JPEG2000. The rate distortion parameter (PSNR) of the proposed scheme is competitive with JPEG and JPEG2000. Figs. (3-4) show the reconstructed RGB images.

(a) Standard JPEG.

(b) Standard JPEG2000.

(c) Proposed Scheme.

Fig. (3) : The reconstructed Lena image from applying the proposed method.

(a) Standard JPEG.

(b) Standard JPEG2000.

(c) Proposed Scheme.

Fig. (4) : The reconstructed Jadriya image from applying the proposed method

Table (1)
The compression results of JPEG and JPEG2000, to encode Lena image.

Method	Quality	C.R.	PSNR
JPEG	99%	5.16	41.7
	90%	9.80	39.5
	72%	15.17	37.2
	53%	20.12	35.3
	38%	25.06	34.4
JPEG2000	2	5.28	46.6
	10	9.98	41.3
	15	14.96	39.0
	20	20.06	37.5
	25	25.24	36.5

Table (2)
The compression results of proposed method, to encode Lena image

np	Φ	s	a	t	h	C.R.	PSNR
1	111	3	0.3	0.5	0	5.01	40.5
2	122	7	0.3	0.25	1	10.28	36.9
3	133	10	0.4	0.25	1	15.00	34.8
3	133	15	0.5	0.25	1	20.21	34.1
3	133	21	0.6	0.25	1	25.21	33.1

Table (3)
The compression results of JPEG and JPEG2000, to encode Jadriya image.

Method	Quality	C.R.	PSNR
JPEG	95%	4.00	41.0
	85%	6.15	37.0
	70%	8.16	34.1
	45%	12.25	31.7
	0%	16.95	29.6
JPEG2000	4	4.02	46.5
	6	5.99	41.5
	8	8.16	37.8
	12	12.03	33.8
	17	16.95	30.9

Table(4)
The compression results of proposed method, to encode Jadriya image

np	Φ	s	a	t	h	C.R.	PSNR
1	111	5	0.3	0.25	1	3.99	39.1
2	112	11	0.3	0.25	1	5.99	35.7
2	122	11	0.6	0.25	1	8.24	33.8
3	133	23	0.6	0.25	1	12.15	29.5
3	133	40	0.6	0.25	1	17.08	26.9

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الخلاصة

إن الطريقة العامة لضغط الصور الملونة تبدأ بتحويلها من نظام RGB إلى إحدى الأنظمة اللونية المناسبة ومن ثم تطبيق إحدى تقنيات ضغط الصور على هذه الأنظمة الجديدة، ثم يتم إعادتها إلى النظام السابق RGB . في هذا البحث تم اقتراح طريقة ترميز ذات كفاءة عالية وتعقيد قليل لضغط الصور الملونة باستخدام التحويل المويجي الثنائي التعامد (Tab3/5) . الطريقة المقترحة تبدا بتحويل الصور من نظام RGB الى النظام اللوني YC_bC_r ثم استخدام التحويل المويجي الثنائي التعامد (Tab3/5),التكميم المنتظم باستخدام التكميم الهرمي متبوعا بطريقة تشريح البتات المطورة لاختيار المعاملات المويجية المهمة لترمز نهائيا باستحدام مرمز هوفمان .ا ظهرت النتائج إلى أن كفاءة المخطط المقترح مشجع عند مقارنته مع حالات "الجيبيك" و "الجيبيك2000.