COLOR IMAGE COMPRESSION USING HYBRID METHOD

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Abstract

In this work, a new color image compression scheme combining the wavelet transform and modified vector quantization (MVQ) method is proposed. In wavelet transform, the vertical and horizontal Haar filters are composed to construct four 2-dimensional filters, such filters applied directly to the image to speed up the implementation of the Haar wavelet transform. Haar wavelet transform was used to map the image to frequency bands, bit allocation process and scalar quantization are implemented on approximation sub-band while modified vector quantization mechanism employed to encode the other higher frequency subbands using small block size and decrease the codebook size as the subband number increases. Since the encoding process is much easier when the range of coded parameters are positive, thus the coefficients values of codebook are mapped to the positive range. Finally S-Shift encoding process is performed. The analysis results have indicated that the proposed method offers a compression performance up to (29/1) with little effects will be noticed on the image quality.

Key Words: Image compression, Haar wavelet filter, Vector Quantization

الخلاصة

في هذا البحث تم اقتراح منظومة تشفير الصور الملونة اعتمدت التحويل المويجي وطريقة التكميم ألاتجاهي المعدلة. في التحويل المويجي إن مرشحات مويجة هار العمودية والأفقية توصف لبناء أربعة مرشحات ثنائية البعد تسلط بشكل مباشر على الصورة لتسريع تنفيذ تحويل مويجة هار. ان تحويل هار المويجي استخدم لنقل بيانات الصورة الى حزم تردد ثم استخدمت طريقة توزيع الثنائيات والتكميم العددي على جزء الحزمة التقريبي بينما نفذت اليه التكميم ألاتجاهي المعدلة لتشفير بقية حزم الموجات ذات التردد العالي باستعمال القطع (البلوكات) ذو حجم صغير مع تقليل حجم الكتاب المشفر مع زيادة رقم حزمة التردد. بما انه عملية التشفير تكون اسهل بكثير عندما يكون مدى المقاطع المشفرة موجبه لذلك فان قيم المعاملات لكتاب الشفرة نقلت ضمن المجال الموجب. أخيرا عملية تشفير ال (S-Shift) قد أنجزت. اظهرت نتائج التحليل ان الطريقة المقترحة تعرض ضغط يصل الى 29/1 مع تأثير قليل يلاحظ على كفاءة الصورة.

Introduction

There are many coding techniques applicable to color image. In our work, some adaptive coding methods have been employed for performing the compression process; all these methods are principally based on using wavelet transform and vector quantization. Wavelet Transform has emerged as a powerful mathematical tool in many areas of science and engineering specifically for data compression. It has provided a promising vehicle for image processing applications, because of its flexibility in representing images and its ability to take into account Human Visual System characteristic. It is mainly used to decorrelate the image data, so the resulting coefficients can be efficiently coded. It also has good energy compaction capabilities, which results in a high compression ratio. It can be viewed as a special case of multirate filter bank with dyadic tree decomposition [1-3]. Wavelets were developed independently in the fields of mathematics, physics, electrical engineering and seismicgeology. Interchanges between these fields during the last ten years have led to many wavelet applications, such as image compression, de-noising, human vision, radar, etc. Also, it is being used in many areas of science and engineering such as: signal processing, fractal analysis , numerical analysis , statistics , and astronomy. Recently, wavelets were determined to be the best way to compress a huge library of fingerprints [4-7]. *F. Murtagh* [8] considers the wavelet transform of a rooted, node-ranked, p-way tree. They focus on the case of binary trees, and a variant of the Haar wavelet transform. They distinguish between two cases: firstly, where the binary tree represents a hierarchy of embedded, non-overlapping subsets of a given set; and secondly, where the binary tree represents an ultrametrically related set of points. N. Jain and R. Vig [9] discussed a wavelet-based Vector Quantization technique for the compression of Electromyogram (EMG) signals. Wavelet coefficients, obtained from EMG signal samples, are arranged to form a set of vectors called Tree Vectors (TVs), where each vector has a hierarchical tree structure. Vector quantization is then applied to these tree vectors for encoding, which uses a pre-calculated codebook. The encoded vector is a set of indexes of the codebook vectors. The codebook is updated dynamically using distortion constrained codebook replenishment method. Finally the signal is decoded using a copy of the same codebook available with encoder.

Wavelet Transform

This section is dedicated to demonstrate the of wavelet compression using Haar filter. In the present work, the mechanism of the WT system is based on the idea of combining the horizontal lowered high pass filters with the vertical corresponding filters to constructed four 2-dimensional Haar filters, the direction implementation of these filters will lead to significant reduction in both coding and decoding process time in comparison with the traditional mechanism which is based on the sequential application of the horizontal followed by vertical filter. The wavelet transform can be shown as in the following steps:

Forward Haar Wavelet Transform

Haar wavelet transform consists of both: low pass and high pass filters is the preferred wavelet because it can be readily implemented in hardware. The high pass and low pass filters are called the decomposition filters because they break the image down or decompose the image into detailed and approximation coefficients, respectively. The approximation band (LL) is the result of applying low pass filter in vertical and horizontal directions, the (LH) band is the result of applying horizontal low pass filter and vertical high pass filter, while the (HL) band is the result of horizontal high pass filter and vertical low pass filter, and finally (HH) band is the result of horizontal and vertical high pass filter. In this transform each (2x2) adjacent pixels are picked as group and passed simultaneously through four filters (i.e., LL, HL, LH, and HH) to obtain the four wavelet coefficients, the bases of these 4-filters could be derived as follows[10]:

The low and high filters are:

$$L = \frac{1}{\sqrt{2}}(1 \quad 1)$$

$$H = \frac{1}{\sqrt{2}}(1 \quad -1)$$

Thus the horizontal low pass followed by the vertical low pass filter is equivalent to:

$$LL = \frac{1}{2}\begin{pmatrix}1\\1\end{pmatrix}(1 \quad 1) = \frac{1}{2}\begin{pmatrix}1 & 1\\1 & 1\end{pmatrix}$$

The horizontal high pass filter followed by vertical low pass filter is:

$$HL = \frac{1}{2}\begin{pmatrix}1\\-1\end{pmatrix}(1 \quad 1) = \frac{1}{2}\begin{pmatrix}1 & 1\\-1 & -1\end{pmatrix}$$

While the horizontal low pass filter followed by vertical high pass filter is equivalent:

$$LH = \frac{1}{2}\begin{pmatrix}1\\1\end{pmatrix}(1 \quad -1) = \frac{1}{2}\begin{pmatrix}1 & -1\\1 & -1\end{pmatrix}$$

and finally, the horizontal high pass filter followed by vertical high pass filter is:

$$HH = \frac{1}{2}\begin{pmatrix}1\\-1\end{pmatrix}(1 \quad -1) = \frac{1}{2}\begin{pmatrix}1 & -1\\-1 & 1\end{pmatrix}$$

Inverse Haar Wavelet Transform

The output of forward Haar wavelet transform is the wavelet coefficients of the (LL, HL, LH, and HH) bands. To reconstruct the image, the same four two dimensional filters (which are mentioned in section (2.1) have been used.

Modified Vector Quantization (MVQ)

In this section we modified the following algorithm for improve the quality of reconstructed images. The main steps of this modification are:

1-For an M × M image, the image is first partitioned into fixed size square blocks, each block of size n × n.

2- Form an initial codebook by choosing the first N-input image vectors as reproduction vectors.

3-Compare each input vector with all N-reproduction vectors. Best match is achieved when the minimum mean square error (MSE) between the reproduction and the input vectors is within a pre-specified threshold. In this case the input matched vectors should be given the same index of the reproduction vector**.**

4- For each index, find the centriod of all input vectors. The centriods are the new codebook.

5- Sort the codebook vectors in descending order from high count to low count.

6- Eliminate the last reproduction vector, which has very low count and split the first reproduction vector (i.e., high count) into two vectors by multiplying the vector contents by enlargement/reduction factors (say, 1.1/0.9) to reproduce two new vectors.

7- The procedure repeats until the process converges to solution, which is a minimum of the total reproduction error.

Wavelet Modified Vector Quantization Scheme (WMVQ)

In this section, we will discuss the proposed compression method based on wavelet transform and modified vector quantization. The suggested method can be divided into process:

A. Encoding process.

The encoding process implies the following steps:

1-Convert the RGB image to YIQ color model

2-Apply forward Haar wavelet transform on luminance component and both chrominance components, individually, to produce (L) number of layers. The total number of subbands will be (3×L+1)

3-Determine the minimum (M_n) and maximum (M_x) values of the approximation subband (LL-band) and then determine their dynamic range (R).

$R = M_x - M_n$

The subband number of the approximation band will be (3×L +1)

4-Determine the number of bits allocated, B, for subband LL by using the following equation:

$B(k) = \text{Log}_2 (R)$ for k=3L+1

5- Determine the quantization coefficients of LL subband by applying the following expression:

$$Q(k) = \frac{R}{2^{B(k)} - 1} \qquad \text{for } k=3L+1$$

6- For each quantization coefficient of subband LL, determine the quantization index (Q_I) by applying scalar quantization to reduce the number of bits needed to represent, approximately, the coefficients as follows:

$$Q_I(xy,k) = \frac{w(x,y,k) - M_n}{Q(k)} \quad \textit{for } k=3L+1$$

Where w(x, y, k) is the wavelet coefficient at the position (x, y) in subband (k), and Q_I (x, y, k) is the corresponding quantization index.

7-Apply (MVQ) mechanism which described in section (3) for middle subbands using small block size. Decrease the codebook size as the subband number increases.

8-Eliminate the highest frequency subbands.

9-For the detailed bands the coefficients values of codebook $W_c(x, y, k)$ will have positive and negative values. Since the encoding process is much easier when the range of coded parameters is positive, thus the determined coefficients are mapped to the positive range by using the following mapping formula:

$$W'_C(x,y,k) = \begin{cases} 2W_C(x,y,k) & \textit{if } W_C(x,y,k) \geq 0 \\ 2|W_C(x,y,k)| + 1 & \textit{otherwise} \end{cases}$$

In this case all positive values will mapped to even values and all negative values will correspond to odd values.

10-Compute the minimum bits for every codebook in each detailed subbands by computing the maximum number in the codebook and compute the minimum bits need it for that subbands

11- S-Shift Encoder; In this stage, the input data are the quantization indices values $Q_I(x, y, k)$ of subband LL and the coefficients values of the subbands (LH, HL, HH) both results have been gathered in a single array. The codewords produced by applying Shift-coding on the array are send to the compression bit stream, which represents the compressed data file

B- Decoding process

The decoding process implies the following steps:

1-Loading the compress data as a one dimensional array of bits.

2-Perform S-Shift decoding, which is opposite to S-Shift encoding. The input to the S-Shift decoder is the length (in bits) of the coefficient value which is previously archived in the compression file by using S-Shift encoder, and the output is the coefficient value.

3-For each quantization index value $Q_I(x,y,k)$ belong to subband LL, apply dequantization process as follows:

$$W'(x,y,k) = \frac{Q_I(x,y,k)\times R}{2^{B(k)}-1} + M_n$$

Where $W'(x,y,k)$ is the reconstructed wavelet coefficient.

4-For each coefficient value belong to detailed subbands, use the inverse MVQ method

5-For each coefficient value $W'_C(x,y,k)$ belong to detailed subbands, use the following inverse mapping equation

$$W_C(x,y,k) = \begin{cases} \dfrac{W'_C(x,y,k)}{2} & \text{if } W'_C(x,y,k) \text{ is even} \\ \dfrac{1-W'_C(x,y,k)}{2} & \text{if } W'_C(x,y,k) \text{ is odd} \end{cases}$$

6-Apply inverse Haar wavelet transform on the reconstructed wavelet coefficient to reconstruct the image. The suggested method was performed on Jadriya colored image, which has 24b/p, and it size is 256x256 pixels(see fig.1).Flowchart of encoding process of the proposed method and decoding process can be shown in figures (2) and (3), respectively.

Figure (1) : Jadriya color image.

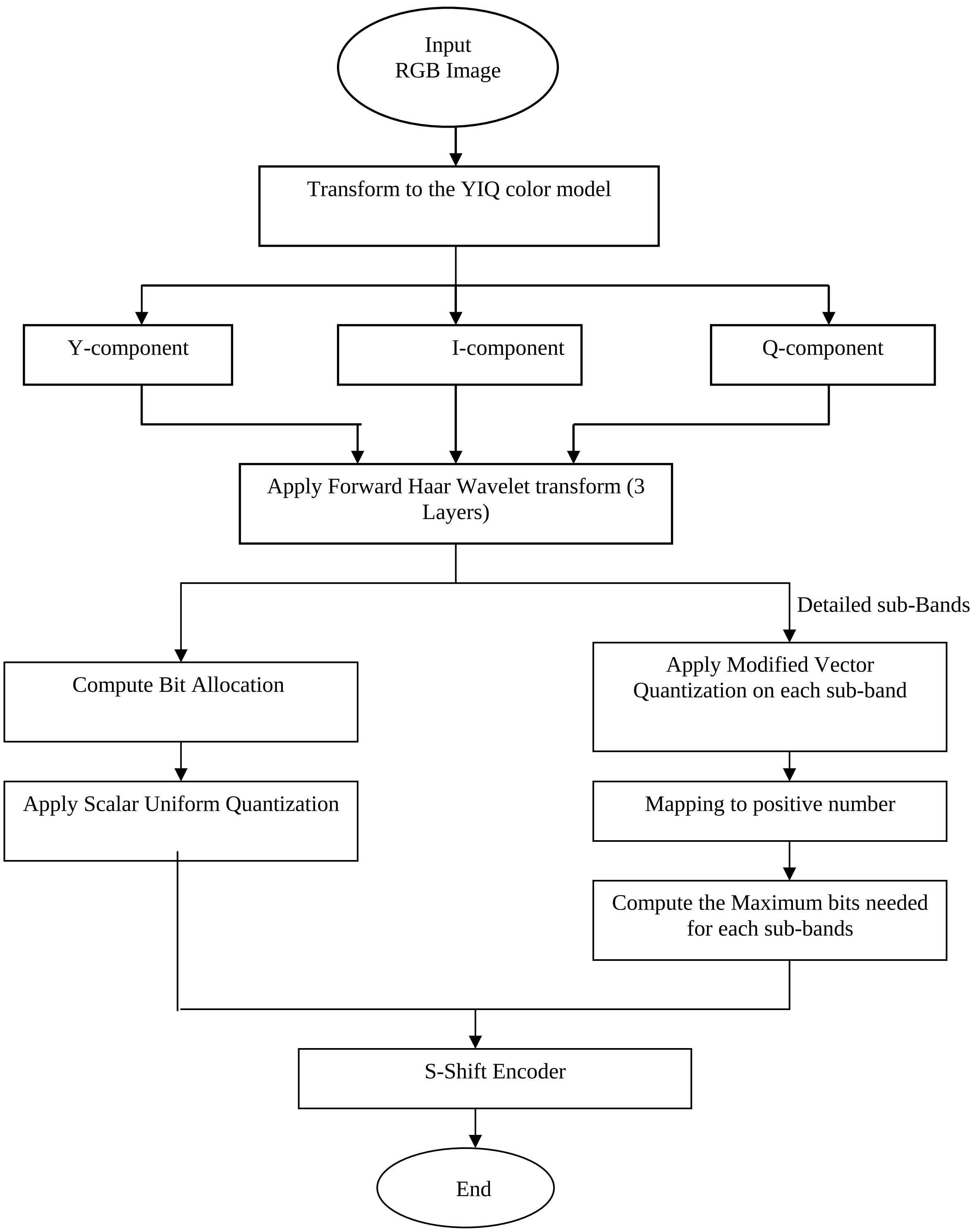

Figure (2) : Flowchart of encoder of suggested method

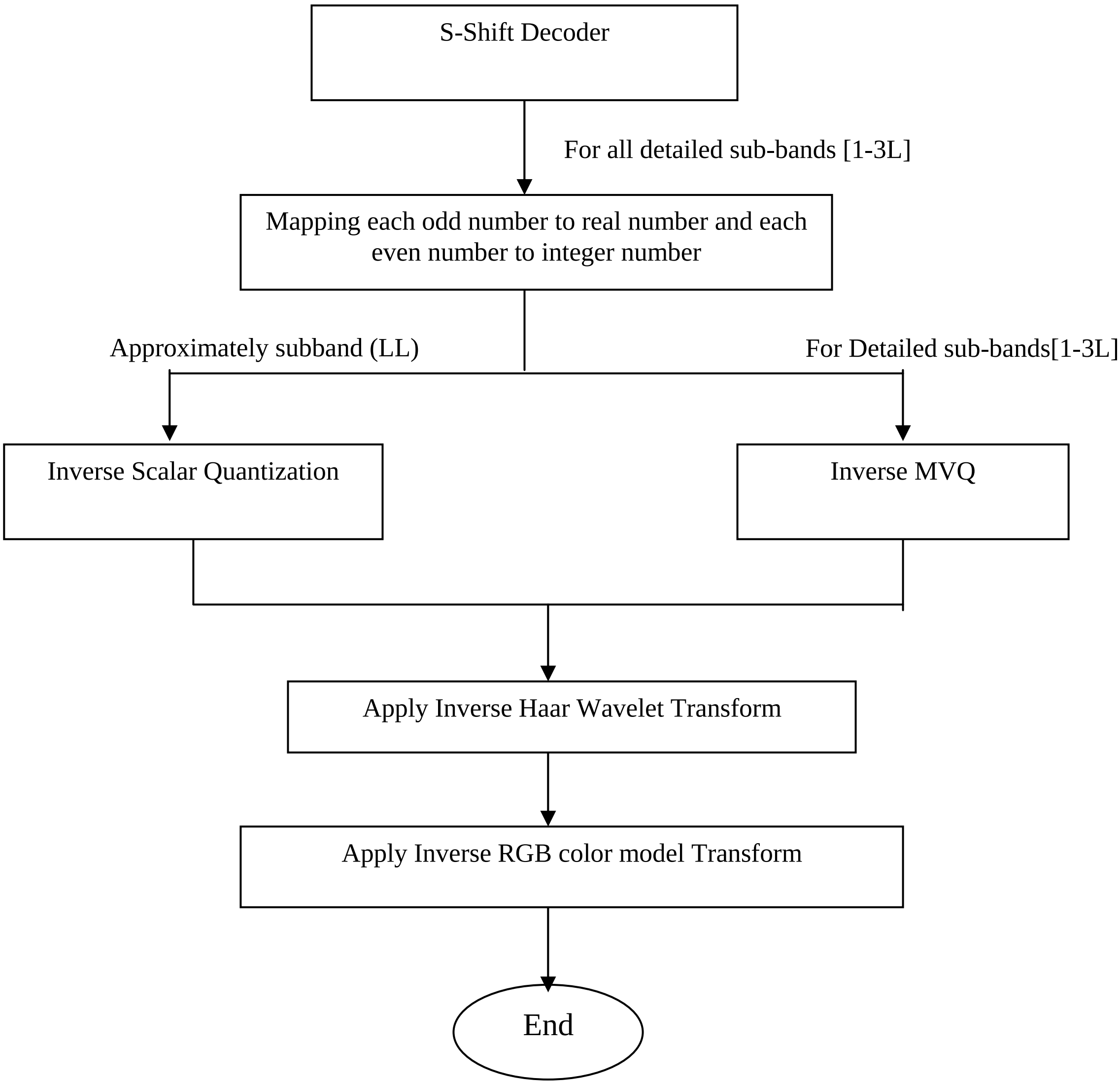

Figure (3): Flowchart of decoder of suggested method

Results and Discussion

The suggested technique is performed separately on the Luminance component and both Chrominance components of colored image to test the proposed method. All involved parameters, implies within this method, were utilized as control parameters to investigate the compression performance of the proposed method. These parameters are:

1. Number of layers.
2. Codebook Size.
3. Block Size.

The effect of these parameters were investigated by considered several cases within the allowable range of their values as shown in tables (1 - 4) , while figure 4 presents the reconstructed RGB images. From the results, Some of the important conclusions could be presented as follows:

1-The compression performance decreases with the increase of block size and decrease the codebook size. Better compression ratio is obtained for smaller codebook size, as less number of bits required to store the index of the codevector.

2- The codebook size refers to the total number of code vectors in the codebook. As the size of codebook increases, the quality of the reconstructed images improves, but the composition ratio reduces and the computational complexity increases. Therefore, there is a trade off between the quality of the reconstructed images and the amount of compression achieved.

3- Very small size of codebooks are utilized for both chrominance components comparing with codebook size for luminance component because most of the image energy is distributed in luminance component and to maintain a relatively high fidelity coding of luminance component to satisfy the human visual system.

4-The proposed method offers a compression performance up to (29/1) with little effects will be noticed on the image quality.

5- The increase in the number of subband layers will increase the degree of energy compactness in the coarse bands, which in turn implies a small relative number of coefficients in comparison with whole number of wavelet coefficients. This fact is the major reason of increasing of layers when large compression ratio is required to attend.

Table (1): The compression performance of the proposed method for Jadriya image with block size 2×2 of Y-component and number of layers=3.

Sub-band Number	Type of Quantization	Codebook Size of Y-component	C.R.	PSNR (dB)
10	scalar	X	X	X
7, 8, 9	vector	128	29.817	22.402
4, 5, 6	vector	64		
1, 2	vector	32		
3	eliminate	X	X	X
10	scalar	X	X	X
7, 8, 9	vector	64	30.421	20.747
4, 5, 6	vector	32		
1, 2	vector	16		
3	eliminate	X	X	X
10	scalar	X	X	X
7, 8, 9	vector	32	31.238	19.436
4, 5, 6	vector	16		
1, 2	vector	8		
3	eliminate	X	X	X

Table (2): The compression performance of the proposed method for Jadriya image with block size 2×2 of Y-component and number of layers=2.

Subband Number	Type of Quantization	Codebook Size of Y-component	C.R.	PSNR. (dB)
7	Scalar	X	X	X
4, 5, 6	Vector	128	20.763	24.074
1, 2, 3	Vector	64		
7	Scalar	X	X	X
4, 5, 6	Vector	64	21.009	22.632
1, 2, 3	Vector	32		
7	Scalar	X	X	X
4, 5, 6	Vector	32	21.305	21.168
1, 2, 3	Vector	16		
1, 2, 3	Vector	16		

Table (3): The compression performance of the proposed method of Jadriya images with block size 4×4 of Y-component and number of layers=3.

Subband Number	Type of Quantization	Codebook Size of Y-component	C.R.	PSNR. (dB)
10	Scalar	X	X	X
7, 8, 9	Vector	32	64.0 25	17.500
4, 5, 6	Vector	16		
1, 2	Vector	8		
3	Eliminate	X	X	X
10	Scalar	X	X	X
7, 8, 9	Vector	16	66.7 58	16.728
4, 5, 6	Vector	8		
1, 2	Vector	4		
3	Eliminate	X	X	X
10	Scalar	X	X	X
7, 8, 9	Vector	8	70.5 13	16.254
4, 5, 6	Vector	4		
1, 2	Vector	2		
3	Eliminate	X	X	X

Table (4): The compression performance of the proposed method of Jadriya images with block size 4×4 of Y-component and number of layers=2.

Subband Number	Type of Quantization	Codebook Size of Y-component	C.R.	PSNR. (dB)
7	scalar	X	X	X
4, 5, 6	vector	128	33.499	20.705
1, 2, 3	vector	64		
7	scalar	X	X	X
4, 5, 6	vector	64	34.183	19.217
1, 2, 3	vector	32		
7	scalar	X	X	X
4, 5, 6	vector	32	34.918	18.350
1, 2, 3	vector	16		

Number of layer = 3
Codebook size of Y-component =128, 64, 32.
Block size of Y-component =2×2.
C.R. = 29.817.
PSNR. = 22.402.

Number of layer = 2
Codebook size of Y-component =128, 64.
Block size of Y-component =2×2.
C.R. = 20.763.
PSNR. = 24.074.

Figure (4): The reconstructed RGB images from applying WMVQ

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