International Journal of
Advances in Scientific Research and Engineering (ijasre)
E-ISSN : 2454-8006
DOI: http://dx.doi.org/10.7324/ IJASRE.2017.32482
Vol.3 (7) Aug - 2017

# Hybrid Image Compression by of Wavelet decomposition, Bit Plane Slicing and Interpolation Techniques

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## ABSTRACT

This paper proposed a hybrid image compression techniques of wavelet transform and bit plane slicing along with utilizing the interpolation scheme of residual base. The results showed the efficiency in compression ratio with high quality.

**Keywords:** Image compression, wavelet transform, polynomial coding and interpolation techniques.

## 1. INTRODUCTION

Image compression is one of the promising technology in the Image Processing field, it became highly demanded with the fast revolution in computer's applications and communication technologies. People are communicate almost all the day time and utilizing digital images to as pass the information through, these images need to be in small data size to help avoid issues regarding to limited memory size and communication band width consuming, so image compression successfully helped reducing the data required to increase the efficiency of using the phones/computers in the communication [1].
Generally speaking, image compression utilizing redundancy that can be grouped into two types, psycho-visual & statistical redundancy. Image compression techniques can fall in one of two types based on the way of exploiting the redundancy, they are lossy or lossless, and each one has its own characteristics and limitations [2]. More details for lossless and lossy techniques can be found in [3-8].
Today, various hybrid compression systems currently in use such as JPEG and JPEG2000, where the former exploited the discrete cosine transform (DCT) while the latter discrete wavelet transforms (DWT) respectively. Details of standard image structures can be found in [9-12].
Researchers attempts to constructs universal hybrid accepted compression systems, including [13] that proposed by Loay and Bushra in 2011,that utilized the wavelet transform and the linear polynomial model along with the quadtree based to compress the residual efficiently using shift encoding techniques, the result show the highly suggested system performance in terms of compression and quality. Also [14] suggested by Ghadah and Haider in 2013, a simple hybrid techniques with the incorporation of multiresolution coding with the linear polynomial techniques, where the integrity of both techniques leads to high efficiency performance. Ghadah [15] in 2013, suggested a hybrid efficient image compression techniques based on exploits the spatial domain effectively of the linear polynomial coding along with the block truncation coding to compress the residual using two level quantizer representation, the results showed the higher performance. Multiwavelet hybrid coding techniques of various block nature, adopted by Ghadah [16] in 2014. Much of the hybrid image compression systems that have been improved until today, can be found in [2, 17-20]

In this paper, a hybrid image compression technique is introduced to compress image loosely, by incorporated the multiresolution scheme of wavelet decomposition along with the interpolation base, also bit plane slicing and polynomial coding techniques. The proposed compression system discussed in section 2 and the results are given in section 3.

## 2. The Proposed Hybrid Compression System

The idea beyond constructs hybrid compression techniques is to increase the efficiency performance of compression ratio with preserving image quality, based on combination between spatial coding and transform coding techniques [21]. This section demonstrates the proposed system in details including Fig. 1 and the following steps:

**<u>Step 1:</u>** Load the uncompressed image *I* of size *N*×*N* of *256* colors, *8* bits per pixel (i.e., grayscale image) to the system

**<u>Step 2:</u>** Apply one layered Haar wavelet transform that simply decompose image *I* into approximation and detail sub bands (*LL*, *LH*, *HL* and *HH*) each of size (*N/2*×*N/2*).

**<u>Step 3:</u>** Converts the details sub bands (*LH*, *HL* and *HH*) images into its layers by utilizing bit-plane slicing (*BPS*) technique, in other words, slice each sub band image into the eight binary images or into eight bit plane images (layers).
In general the intensity value of each pixel can be represented by an 8-bit binary vector ($b_7$, $b_6$, $b_5$, $b_4$, $b_3$, $b_2$, $b_1$, $b_0$), it ranges from bit level 0 ($layer_0$) to bit level 7 ($layer_7$) [22].
The lower order bits (lowest four layers) of small image contribution effects removed (i.e., least significant bits (*LSB*) from $layer_0$ to $layer_3$), without visual degradation of image appearance, and only the significant layers of highly effect used (i.e., most significant bits (*MSB*) from $layer_4$ to $layer_7$) then coded using the simple popular run length coding techniques.

**<u>Step4:</u>** Apply the polynomial coding of linear base along with the interpolation technique to efficiently compress the approximation sub band (*LL*) image, using the following sub steps:

1- Partition the approximation sub-band (*LL*) image into no overlapping blocks of fixed size *n*×*n*, and computes the approximated linear polynomial coefficients according equations (1-4) [13].

$$a_0 = \frac{1}{n \times n} \sum_{i=0}^{n-1} \sum_{j=0}^{n-1} LL(i,j) \quad \ldots\ldots\ldots(1)$$

$$a_1 = \frac{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} LL(i,j) \times (j - x_c)}{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} (j - x_c)^2} \quad \ldots\ldots(2)$$

$$a_2 = \frac{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} LL(i,j) \times (i - y_c)}{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} (i - y_c)^2} \quad \ldots\ldots(3)$$

$$x_c = y_c = \frac{n-1}{2} \quad \ldots\ldots\ldots(4)$$

Where *LL (i, j)* is the approximation sub-band of original image of size (*N/2*×*N/2*) and block of size (*n*×*n*)

2- Use the uniform scalar quantization base technique to quantize/dequantize the computed polynomial approximation coefficients, where each coefficient is quantized using different quantization step.

$$a_0Q = round\left(\frac{a_0}{QS_{a0}}\right) \rightarrow a_0D = a_0Q \times QS_{a0} \quad \ldots\ldots(5)$$

$$a_1Q = round\left(\frac{a_1}{QS_{a1}}\right) \rightarrow a_1D = a_1Q \times QS_{a1} \quad \ldots\ldots(6)$$

$$a_2Q = round\left(\frac{a_2}{QS_{a2}}\right) \rightarrow a_2D = a_2Q \times QS_{a2} \quad \ldots\ldots(7)$$

Where $a_0Q, a_1Q, a_2Q$ are the polynomial quantized values, $QS_{a0}, QS_{a1}, QS_{a2}$ are the quantization steps of the polynomial coefficients, and $a_0D, a_1D, a_2D$ are polynomial dequantized values.

3- The predicted image $\tilde{LL}$ is an approximation of the original *LL*, created by using the dequantized polynomial coefficients for each encoded block representation.

$$\tilde{LL} = a_0D + a_1D(j - x_c) + a_2D(i - y_c) \quad \ldots\ldots(8)$$

4- Calculate the residual error as difference between the original approximation sub-band (*LL*) and the predicted one $\tilde{LL}$ .

$$R(i,j) = LL(i,j) - \tilde{LL}(i,j) \quad \ldots\ldots(9)$$

Where *R* corresponds to high resolution residual image of size (*N/2*×*N/2*) (i.e., *128*×*128*).

5- Shrinking the residual image by applying the interpolation layered technique of nearest neighbour base, namely the resultant residual image interpolated to create the first shrinked residual image $R_1$, then this shrinked image also interpolated again to create the second shrinked residual image *R2* corresponding to medium and lower layers respectively (i.e., $R_1$ of size *64*×*64* and $R_2$ of size *32*×*32*).

6- Quantized/dequantized the second shrinked residual image of lower resolution image $R_2$ using the scalar uniform base.

$$R_2Q = round(\frac{R_2}{QS_{R_2}}) \rightarrow R_2D = R_2Q \times QSR_2 \text{ .............. } (10)$$

Where $R_2Q$ is the lower shrinked residual image of size *32×32*, $QS_{R_2}$ the quantization step and $R_2D$ the dequantized values

7- Create the enlarged interpolated image of medium size (*64×64*) using the dequantized second residual image $In_{Med}[\tilde{R}_2]$

8- Find the first difference image between the shrinked image of medium resolution $R_1$ and the interpolated one from the step above.

$$d_1 = R_1 - In_{Med}[\tilde{R}_2] \text{......................} (11)$$

9- Quantize/dequantized the first difference image using the simple scalar uniform base, such as:

$$d_1Q = round(\frac{d_1}{QS_{d_1}}) \rightarrow d_1D = d_1Q \times QS_{d1} \text{ .................... } (12)$$

10- Construct the approximated medium resolution image $\tilde{Y}_1$ as a sum of interpolated one $In_{Med}[\tilde{R}_2]$ along with the first dequantized difference image.

$$\tilde{Y}_1 = In_{Med}[\tilde{R}_2] + d_1D \text{ ................................. } (13)$$

11- Create the enlarged interpolated image of high resolution image (*128×128*) using the approximated medium resolution image $In_{Hgt}[\tilde{R}_1]$

12- Find the second difference image between the original image *LL* and the interpolated one from the step above.

$$d_2 = LL - In_{Hgt}[\tilde{R}_1] \text{.........................} (14)$$

13- Quantize/dequantized the second difference image using the simple scalar uniform base, such as:

$$d_2Q = round(\frac{d_2}{QS_{d_2}}) \rightarrow d_2D = d_2Q \times QS_{d_2} \text{ ....................} (15)$$

14- Construct the approximated high resolution image $LL_R$ as a sum of interpolated one $In_{Hgt}[\tilde{R}_1]$ along with the second dequantized difference image.

$$LL_R = In_{Hgt}[\tilde{R}_1] + d_2D \text{ .......................... } (16)$$

15-Apply Huffman coding techniques encode the quantized polynomial coefficients, dequantized difference images.

16- Build the compressed image by adding the predicted image $\tilde{LL}$ to the interpolated residual image $LL_R$

$$\hat{LL}(i,j) = \tilde{LL}(i,j) + LL_R(i,j) \text{........} (17)$$

**Step 5:** Apply the inverse wavelet transform to construct the approximated compressed image $\hat{I}$ of combination base of bit-plane slicing and polynomial coding

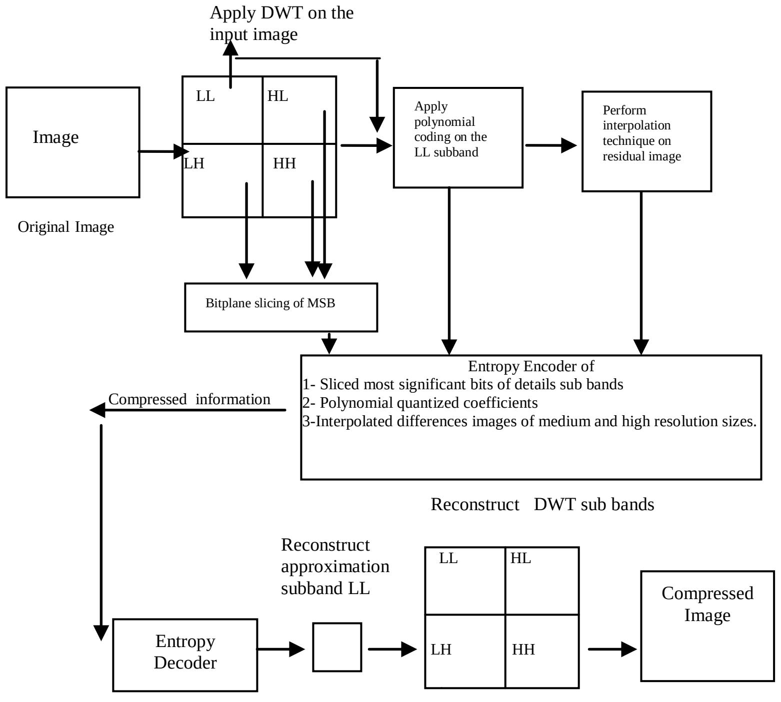


**Fig. 1: Compression system structure of encoder/decoder.**

## 3. EXPERIMENTAL RESULTS

Experiments were done to evaluate the proposed compression techniques performance in terms of compression ratio (CR) and the objective fidelity criteria of peak-signal-to- noise ratio (PSNR). They were tested on a number of well-known standard images, as shown in Fig. 2, where all the images of 256 gray levels (8bits/pixel) of size 256×256, using block sizes of 4×4 of approximation subband polynomial coding techniques along with nearest neighbour interpolation of two layer scheme, and various numbers quantization steps values.


a


b


c

**Fig. 2: Tested images (a) Lena, (b) Rose and (c) Pepper, all images of size 256×256, gray scale images.**

**Table.1: performance of the proposed techniques**

| Tested images | Block Size of 4x4 with quantization coefficients of 1,2,2 respectively | | | CR | PSNR |
|---|---|---|---|---|---|
| | Quantization step of lower level | Quantization step of medium level | Quantization step of higher level | | |
| *Lena* | 5 | 10 | 5 | 8.9622 | 44.9431 |
| | 5 | 10 | 10 | 10.2753 | 38.8775 |
| | 5 | 10 | 15 | 11.3738 | 35.3635 |
| | 5 | 10 | 20 | 12.3281 | 32.8887 |
| | 10 | 10 | 10 | 10.7719 | 38.8654 |
| | 10 | 15 | 10 | 11.0928 | 38.8620 |
| | 10 | 15 | 20 | 13.4405 | 32.9363 |
| | 20 | 10 | 5 | 9.4514 | 43.0013 |
| | 20 | 10 | 20 | 13.2396 | 32.8846 |
| *Rose* | 5 | 10 | 5 | 10.6910 | 45.2748 |
| | 5 | 10 | 10 | 12.3746 | 39.2513 |
| | 5 | 10 | 15 | 13.7450 | 35.6624 |
| | 5 | 10 | 20 | 15.0312 | 33.0469 |
| | 10 | 10 | 10 | 12.9262 | 39.3160 |
| | 10 | 15 | 10 | 13.3475 | 39.2896 |
| | 10 | 15 | 20 | 16.4084 | 33.0534 |
| | 20 | 10 | 5 | 11.3267 | 45.0248 |
| | 20 | 10 | 20 | 16.2459 | 33.0467 |
| *Pepper* | 5 | 10 | 5 | 10.4657 | 45.2537 |
| | 5 | 10 | 10 | 11.9635 | 39.1780 |
| | 5 | 10 | 15 | 13.3041 | 35.5113 |
| | 5 | 10 | 20 | 14.2656 | 32.8254 |
| | 10 | 10 | 10 | 12.5260 | 39.4217 |
| | 10 | 15 | 10 | 12.8452 | 39.2833 |
| | 10 | 15 | 20 | 15.5078 | 32.7957 |
| | 20 | 10 | 5 | 11.9404 | 44.8298 |
| | 20 | 10 | 20 | 15.3336 | 32.7332 |

The results shown in table (1) illustrate performance of the proposed techniques, where the relationship between the compression ratio, quality and quantization steps. It is obvious the trade-off or inverse relation between the compression ratio and the desired. Since the details sub bands values are very small, therefore the utilizing of bit plane slicing (BPS) improve the compression ratio (CR), due to removing the least significant bits (LSB) and preserving only the most significant bits (MSB).

The results also showed that the effect of the equalization steps of different layers residual images, where the lower level affecting the results, since the error propagate towards the up layers.

Lastly, the integration between the polynomial coding and the interpolation base to compress the approximation subband, overcome the residual size problem, by shrinked the residual bottom layers, then hierarchal constructs the up layers with less bytes consumptions.

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