Weighted Bit Rate Allocation in JPEG2000 Tile Encoding

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Abstract

Equal bit rate is assigned to all tiles of an image when compressed with JPEG2000 standard. This bit rate is selected without taking information contents of the tiles into account. This results into poor performance of JPEG2000 standard for the tiles that have higher complexity. We can improve performance of JPEG2000 by assigning higher bit rates to complex tiles. An entropy based weighted bit rate allocation algorithm is proposed in this paper. Experimentations using the proposed algorithm indicate an improvement of up to 2 dB in Peak Signal to Noise Ratio ($PSNR$) and up to 5.352% improvement in Relative Percentage Improvement (RPI) in $PSNR$ in the JPEG2000 reconstructed images.
Keywords: JPEG2000, $PSNR$, MSE, Entropy, Tiles, RPI.

1. Introduction

JPEG2000 is a state-of-art image and video compression standard. It provides better compression performance and other features like region of interest (*ROI*) coding, quality scalability, transmission scalability etc. as compared to the JPEG image compression standard [1-5]. It allows an image to be divided into rectangular blocks of same size called tiles, before compressing the image. In compression process of JPEG2000 encoder, equal bit rate is assigned to each tile of the image. This assignment is suitable for the images with information contents equally distributed throughout the image. However, tiles of an image may have different complexities. Some of the tiles may have larger texture area while others may have larger smooth area. The quality of a reconstructed image varies a lot if all tiles in the image do not have same complexity. As such, we should include the complexity of a tile while assigning a bit rate to it. This is a known fact that entropy of a complex tile is more than the entropy of smooth tile. So, we have here proposed a method to assign bit rate to a tile based on the weights derived using the entropy of a tile. Using this algorithm, tiles of an image have assigned different compression bit rates. Visual quality of reconstructed image is improved by assigning these bit rates to the tiles of an image.

2. Related Work

It is a well known fact that human beings pay more attention to important areas of an image. Motivated by this, Battiato *et al.* [6] proposed a method for allocating bit rate to different tiles of an image on the basis of index of the information content of each tile. Ardizzone *et al.* [7] proposed an adaptive method to assign more bits to the image regions in which errors are more visible, maintaining the global bit rate unchanged. Effectiveness of their method depends on the accuracy of the region classifier. Liu *et al.* [8] proposed an algorithm using the complexity of a tile and motion activity of the tile. However, their algorithm is applicable to the Motion JPEG2000 video sequences only.

3. Proposed Algorithm and Quality Comparison Parameters

3.1 Overview of JPEG2000 Encoder

JPEG2000 encoder consists of many processes, as shown in Fig.1. It allows image to be divided into tiles if the size of the image is very large or the memory available is low. This process is known as tiling. Each tile of an image is compressed independently. After tiling, discrete wavelet transform (*DWT*) is applied on each tile. *DWT* is a subband transform which transfers image/tile from spatial domain to frequency domain. To achieve efficient lossy and lossless compression within a single encoder, two wavelet transforms are employed. The 5/3 reversible and 9/7 irreversible wavelet transforms are chosen for lossless and lossy compressions respectively.

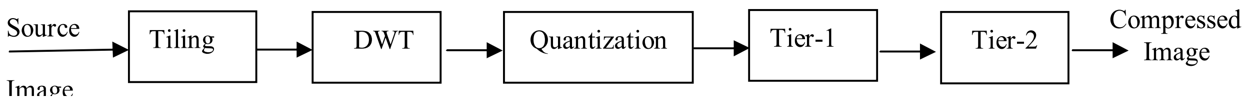


Fig. 1: Block Diagram of JPEG2000 Encoder

After this transform, the wavelet coefficients are quantized to reduce the precision if the lossy compression is chosen. Then wavelet coefficients are entropy encoded by Embedded Block Coding with Optimized Truncation (*EBCOT*) which is a two tier coding algorithm. In *EBCOT*, each wavelet subband is divided into code-blocks. The coefficients of a code-block are represented by their sign-magnitude and encoded from the most significant bit plane to the least significant bit plane by tier-1. Each bit plane is encoded with three coding passes. These passes are significant propagation pass, magnitude refinement pass and cleanup pass. Each pass generates independent bit stream. Finally tier-2 reorders these bit streams into final JPEG2000 output image with rate distortion slope optimized property and the features specified by the user.

3.2 Proposed algorithm

Weighted bit rate allocation method is illustrated in Fig. 2. In this allocation, the weights are derived from the entropy of tiles of an image. This bit rate allocation is passed to the tier-2 process of *EBCOT*, which assigns different bit rate to bit streams of each tile of the source image. After this, the final bit stream is generated by the tier-2 to output the compressed image.

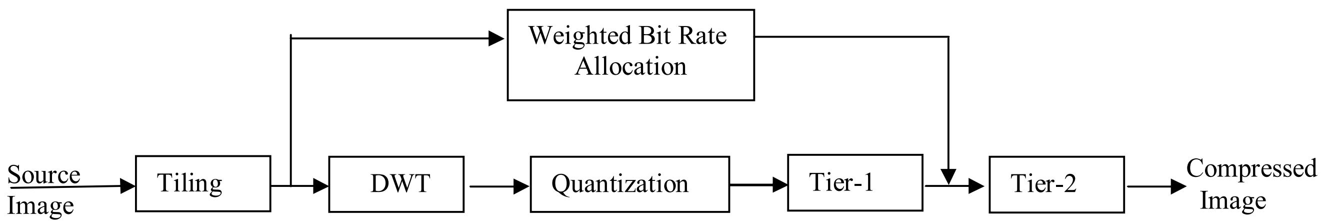


Fig. 2: Block Diagram of JPEG2000 Encoder with weighted bit rate allocation

The entropy *e* of an image is defined as,

$$e = -\sum_{i=1}^{N} P(a_i) \log \left(P(a_i)\right) \qquad (1)$$

where a_i, $i = 1, 2, \ldots, N$, is the value of i^{th} gray level of original image, N is the total number of different gray levels in the image and $P(a_i)$ is the probability of gray level a_i of the image.

Using this definition, entropy of each tile can be calculated. The weight $w(t)$ assigned to tile *t* is calculated as,

$$w(t) = \frac{e(t)}{\sum_{t=1}^{N_T} e(t)} \times N_T \qquad (2)$$

where $e(t)$ is entropy of t^{th} tile and N_T is total number of tiles in the image. This can also be noted that,

$$\frac{\sum_{t=1}^{N_T} w(t)}{N_T} = 1 \qquad (3)$$

Number of bits N_b, assigned to a JPEG2000 compressed image is calculated as,

$$N_b = R_0 \times image\_size,$$

where R_0 is the global compression bit rate given by the user and *image_size* is the size of the original image.

Weighted bit rate R_i, based on the entropy, is now assigned to each tile, using the following formula.

$$R_t = R_0 \times w(t) \qquad (4)$$

Thus total number of bits N_b' assigned to the compressed image is given by,

$$\begin{aligned} N_b' &= \sum_{t=1}^{N_T} R_t \times tile\_size \\ &= \sum_{t=1}^{N_T} R_0 \times w(t) \times tile\_size \\ &= R_0 \times N_t \times tile\_size \\ &= R_0 \times image\_size \\ &= N_b \end{aligned} \qquad (5)$$

where *tile_size* is the size of a tile. Eq. (5) shows that total number of bits assigned to the compressed image remains unchanged when the image is compressed using proposed algorithm. The above steps can be summarized in the following algorithm.

Algorithm: Weighted bit rate allocation algorithm
Step 1: Calculate the entropy and weight of each tile of the original image using Eq. (1) and Eq. (2), respectively.

Step 2: Assign weighted bit rate to each tile using Eq. (4). Then compress each tile using JPEG2000 coder.

3.3 Quality Comparison Parameters:

Quality comparison parameters considered in this work are $PSNR$ and RPI in $PSNR$ values. $PSNR$ is determined between the original image and reconstructed image using the following formula.

$$PSNR = 10\, log_{10} \frac{\left(2^B - 1\right)^2}{MSE} \quad (6)$$

where B is the bit depth of the image and MSE is the mean square error and is defined as,

$$MSE = \sum_{m=1}^{x} \sum_{n=1}^{y} \frac{(A_{mn} - B_{mn})^2}{x \times y}$$

where A_{mn} is the pixel of reconstructed image and B_{mn} is the pixel of original image, x and y are the height and width of the images, respectively.

RPI in $PSNR$ is defined as

$$\frac{PSNR_{new} - PSNR_{old}}{PSNR_{old}} \times 100 \quad (7)$$

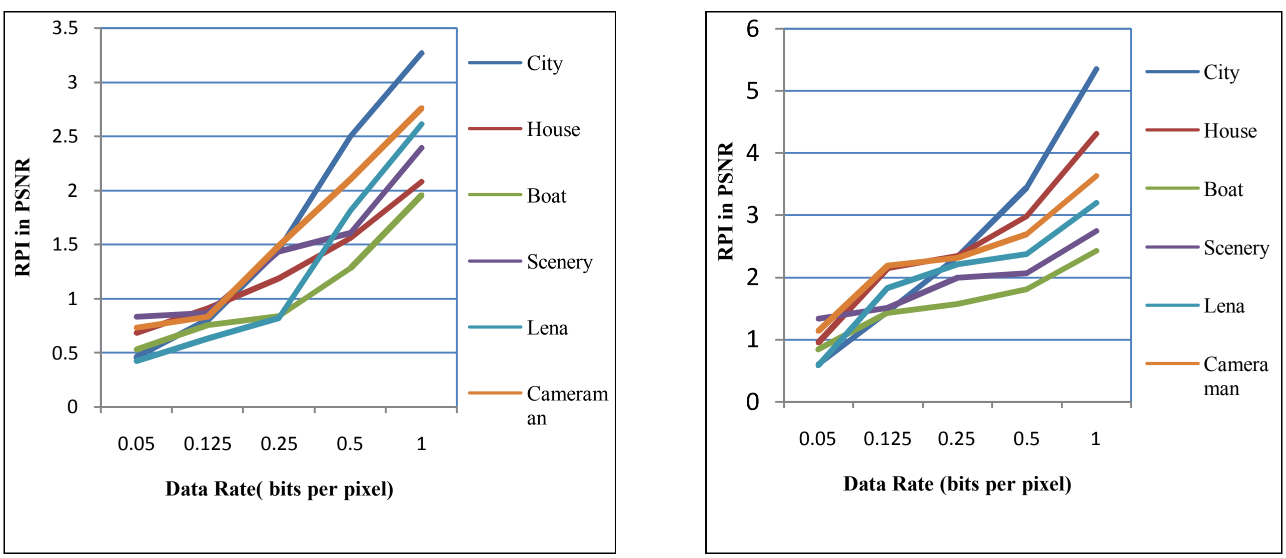
where $PSNR_{new}$ is the $PSNR$ value when proposed algorithm is used with JPEG2000 encoder and $PSNR_{old}$ is the $PSNR$ when existing algorithm is used with JPEG2000 encoder.

4. Results

To implement the proposed algorithm, we modified Kakadu software [9]. In this work, we have considered six standard images taken from literature. These images are compressed using 5 levels wavelet decomposition and a code block size of 64 × 64. In order to demonstrate effectiveness of the proposed algorithm, five bit rates, namely, 1.000, 0.500, 0.250, 0.125 and 0.050 have been considered for each of these six images. The results of this experiment are presented in Table 1.

An analysis of these results is presented in Fig. 3. This contains RPI in $PSNR$ values for images considered in this work for different bit rates. Fig. 3(a) depicts RPI in $PSNR$ values as a function of data rate when the percentage improvement is calculated on the basis of proposed algorithm and algorithm proposed in [7]. Also, Fig. 3(b) depicts this RPI in $PSNR$ values when the percentage improvement is calculated on the basis of proposed algorithm and standard algorithm used in JPEG2000. In Fig. 3(a) $PSNR$ values vary from 1.687% to 3.25% when bit rate is 1.000; vary from 1.246% to 2.560% when bit rate is 0.500; vary from 0.821 % to 1.804% when bit rate is 0.250; vary from 0.696% to1.351 when bit rate is 0.125 and vary from 0.424% to 0.835 % when bit rate is 0.050, as is indicated from Fig. 3(a).

Fig. 3(b) indicates that RPI in $PSNR$ values vary from 2.403% to 5.352% when bit rate is 1.000; vary from 1.815% to 3.4495% when bit rate is 0.500; vary from 1.5693 % to 2.3369% when bit rate is 0.250; vary from 1.4234% to 2.1920 when bit rate is 0.125 and vary from 0.5875% to 1.3359% when bit rate is 0.050 for the six images considered in this work.



(a) (b)

Fig. 3: RPI in $PSNR$ values

Table 1: $PSNR$ comparison of the proposed algorithm with the existing algorithms

Image	Compression Rate (bit per pixels)	$PSNR$ using JPEG2000 Standard	$PSNR$ using algorithm in [7] with JPEG2000 Standard	$PSNR$ using proposed algorithm with JPEG2000 Standard
City	1.000	36.71	37.45	38.73
	0.500	30.94	31.22	32.15
	0.250	27.32	27.57	27.98
	0.125	24.78	24.95	25.16
	0.050	18.79	18.83	18.93
House	1.000	29.55	30.21	30.84
	0.500	27.03	27.41	27.84
	0.250	25.08	25.37	25.68
	0.125	22.44	22.76	22.94
	0.050	19.59	19.81	19.99
Boat	1.000	35.55	35.72	36.43
	0.500	31.69	31.86	32.27
	0.250	28.41	28.61	28.86
	0.125	25.75	25.92	26.15
	0.050	22.29	22.35	22.49
Scenery	1.000	44.74	44.90	45.98
	0.500	40.81	40.99	41.66
	0.250	36.93	37.14	37.67
	0.125	34.07	34.29	34.59
	0.050	20.88	20.99	21.17
Lena	1.000	33.16	33.35	34.23
	0.500	31.21	31.38	31.96
	0.250	28.95	29.35	29.60
	0.125	24.80	25.09	25.25
	0.050	21.02	21.05	21.15
Cameraman	1.000	44.37	44.75	45.99
	0.500	38.08	38.29	39.11
	0.250	32.96	33.24	33.75
	0.125	28.60	28.98	29.23
	0.050	22.75	22.85	23.03

This can also be inferred from Table 1 that $PSNR$ values for all images and for all bit rates is improved when the proposed algorithm is used vis-a-vis the algorithm implemented in JPEG2000 standard and algorithm proposed in [7].

5. Conclusions

In this paper, a weighted bit rate allocation algorithm for JPEG2000 image tiles has been proposed. The proposed methodology improves the $PSNR$ values for all images and for all bit rates considered in this work. It has been observed that the proposed methodology provides better visual quality in JPEG2000 reconstructed images than the conventional approach of JPEG2000 standard. This improvement has been shown taking place when compared with JPEG2000 encoder and also with the algorithm proposed by Ardizzone *et al.*[7].

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