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An efficient rate control algorithm for JPEG2000 based on reverse order

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Abstract: The JPEG2000 image compression standard is the powerful encoder which can provide phenomenal rate-control performance. The post-compression rate-distortion (PCRD) algorithm in JPEG2000 is not efficient. It requires encoding all coding passes even though a large contribution of them will not be contained in the final code-stream. Tier-1 encoding in the JPEG2000 standard takes a significant amount of memory and coding time. In this work, a low-complexity rate distortion method for JPEG2000 is proposed. It is relied on a reverse order for the resolution levels and the coding passes. The proposed algorithm encodes only the coding passes contained in the final code-stream and it does not need any post compression rate control part. The computational complexity of proposed algorithm is negligible, making it suitable to compression and attaining a significant performance. Simulations results show that the proposed algorithm obtained the PSNR values are comparable with the optimal PCRD.

Key words: image coding; JPEG2000; post compression rate distortion (PCRD); rate control

1 Introduction

With the development of the information technology, the efficient use of bandwidth is one of the main topics in compressing digital images. Rate distortion is important to control the bit rate of image coding and memory requirement. The final goal of rate distortion is to allocate the target bit rate into an image such that the fully distortion can be minimized. JPEG2000 is a strong standard to encode digital images. The encoding algorithm of JPEG2000 is relied on embedded block coding with optimized truncation (EBCOT) [1]. It divides the wavelet coefficient into code blocks and the code-blocks are then encoded by bit-plane coding. After that an optimal bit allocation process is applied and is send to as post-compression rate-distortion (PCRD) algorithm. Although PCRD algorithm achieves the optimal results, since PCRD requires encoding all the coding passes, most of the computation and working memory could be weighed redundant. New rate distortion algorithms for JPEG2000 have been proposed in recent years maintaining the coding performance similar to optimal PCRD.

RODRIGUEZ et al [2] have proposed two strategies based on the lossless decoding of JPEG2000 code-streams. Lossless coding method makes it possible to achieve high compression ratios and result in images without significant distortion. PETERS and KITAEFF [3] have proposed a quantitative analysis of the effects of JPEG2000 image compression standard on the quality of the radio astronomy images. RAMAMURTHY [4] has proposed a strategy for rate distortion in motion JPEG2000. Rate control on the selected frames of the series is performed under the selected-frame-rate-allocator phase. In another phase the MotionJPEG2000 rate allocator utilizes an adaptive Lagrange multiplier to allocate rate to the remaining frames. GHODHBANI et al [5] have proposed a parallel bit plane coding (BPC) scheme, in which three coding passes operate in parallel mode and develop separately. LLINANS [6] has proposed an arithmetic entropy coder that produces fixed-length code-words. The main benefit of the proposed arithmetic coder is that it does not perform renormalization stage and thus decreases computational complexity.

LLINANS et al [7] have proposed the USDQ algorithm by applying the 2SDQ in cells (small groups of coefficients) within a code-block. RDO techniques combined with the proposed cell-based 2SDQ algorithm code high quality images. The proposed cell-based 2SDQ performance is better than previous strategy. SHU

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et al [8] have proposed an image coding algorithm with a rate-distortion optimized WBCT decomposition and on a development packet partitioning coding scheme. In this work the scalar quantizer is applying in each sub-band dependently. LLINANS [9] has proposed a 2-step scalar dead-zone quantization (2SDQ) model. The 2SDQ model is based on two quantization step sizes that approximate wavelet coefficients and a RDO technique that adapts the distortion produced when encoding 2SDQ indexes. RAMAMURTHY [10] has proposed an efficient algorithm for rate distortion in sub-band based image compression schemes like JPEG2000. It utilizes an optimized tree structure which is continuously updated with real slopes. LIU et al [11] have proposed an image coding method based on rate-distortion optimized OFRPT decomposition and on packet-partitioning coding scheme which quantizes each sub-band independently.

LI et al [12] have proposed a simple rata pre-allocated method. At first the wavelet transform was applied to image, and then pre-allocated the real contribution rate for all sub-bands. Finally, when each sub-band has been coded, the code-streams have been truncated pursuant to the pre-allocated rate. CHEN and XU [13] have proposed a low-complexity rate distortion algorithm for JPEG2000. A varied threshold value is used to select the coding passes of each code block during Tier-1 coding stage. Only the selected coding passes during Tier-1 stage are encoded at Tier-2 coding stage. This algorithm needs no lists and thus is reduced working memory.

MERT et al [14] have proposed an implementation of new RDO algorithm for JPEG2000. The proposed algorithm is the low-complexity and detects optimal truncation (OT) point for rate distortion in parallel mode. LLINAS and MARCELLIN [15] have proposed the classical scanning orders of bit-plane image coders that using some the critical strategies understood from rate–distortion theory. The use of these strategies allows to individualizing those features of the bit-plane image coder that are necessary from another features. GRANADO et al [16] have proposed several rate control algorithms for the non-embedded image coder (LTW). In these coders working memory and coding time are serious for suitable operation. In order to reduce calculations, complexity in kind of coder precise rate control is not used. STUTZ and UHL [17] have proposed two algorithms for rate-control optimization wavelet packet basis selection in JPEG2000. The maximum performance increases of the common wavelet packets in JPEG2000 algorithm are calculated. HUANG and DAI [18] have proposed a new and low-memory coder for on-board image compression. The proposed coder is very quick because it does not require any arithmetic coding and RDO. MILANI [19] has proposed a calculation complexity reduction scheme that intends on reducing the calculations of the Tire-1 coding stage with a negligible loss in terms of PSNR. This scheme is based on selecting a decreased set of prediction modes pursuant to their probabilities. AN and CAI [20] have proposed an effective rate control algorithm that uses a fractional upturned shift of bit-plane to analogize more detailed sub-band weighting. AULI-LLINAS et al [21] have proposed the rate control algorithm based on coding passes interleaving (CPI). This simple method selects the passes included in the output code-stream using a simple scanning order based on the significance levels.

2 Analysis of JPEG2000

JPEG2000 is an international image compression standard. Our attention will be on the Part I of the standard called core coding system. JPEG2000 stages are as follows: the discrete wavelet transform (DWT), scalar quantizer, converting to bit-plane, arithmetic entropy coding and rate allocator. The DWT partitions an image into sub-bands. The coefficients in each sub-band introduce horizontal and vertical spatial frequency specifications of the image. In next stage a scalar quantizer is applied in each sub-band and then divided into code-blocks (define size of 64×64). Each code-block is entropy encoded and converts to bit-stream. Each of the code-block bit-stream can be truncated by PCRD algorithm to achieve the target bit rate.

2.1 Wavelet transform

The JPEG2000 image compression standard is transform-based coder. This kind of coder provides efficient compression performance with low complexity. In the DWT-based coder, the image pixels are converted from the space domain to the transform domain. The DWT compacts pixels energy into a small number of coefficients. The DWT is applied in the horizontal and vertical directions of image separately because the computational complexity is greatly decreased. An image is first passed through a horizontal wavelet filter, which results in two sub-bands. Each sub-band then filters in the vertical direction. The image is thus decomposed into four sub-bands, sub-band LL (which is passed through low pass horizontal and vertical filter), LH (which is passed through low pass vertical and high pass horizontal filter), HL (which is passed through high pass vertical and low pass horizontal filter) and HH (which is passed through high pass horizontal and vertical filter). The wavelet transform is a linear transform, so it is possible to switch the horizontal and vertical wavelet filter, and still achieve the same results.

2.2 Quantization

After the wavelet transform stage, all wavelet coefficients are quantized by the following:

$$W_{m,n} = \text{sign}(S_{m,n})\left\lfloor \frac{|S_{m,n}|}{\Delta_b} \right\rfloor \tag{1}$$

where $S_{m,n}$ is the wavelet coefficient; $W_{m,n}$ is the quantized coefficient; Δ_b is the quantization step size; sign(S) represents the sign of coefficient S and $\lfloor S \rfloor$ turns the largest integer that is equal to or less than s. The quantization stage converts the floating wavelet into integer coefficients so that they can be more simply processed by the entropy arithmetic coding stage. The quantization step size Δ_b does not determine the quality of compressed image.

2.3 Entropy coding

After the quantization stage, each code-block is independently encoded through a sub bit-plane coding strategy. In JPEG2000 the output bit-stream of the entropy coder for each code-block is embedded and thus the bit-stream can be truncated and still decodable. The output of the block entropy coder includes the embedded bit-stream and a rate distortion curve that measures the produced distortion of the code-block at the end of each sub bit-plane. As mentioned above, each code-block is encoded, independently. The quantized wavelet coefficients are encoded from the most significant bit-plane (MSB) toward the least significant bit-plane (LSB). Each coefficient bit to be encoded in one of the three coding passes called significance pass, refinement pass and cleanup pass. The significance pass contains bits of the coefficients that are not significant, but have at least one significant neighbor. The refinement pass contains bits of the coefficients that are not significant and the cleanup pass consists of the bits of the coefficients that are not significant and have no significant neighbors. The coding pass data are then arithmetic encoded.

2.4 PCRD algorithm

Rate control process is one of the main features of the JPEG2000 standard. The exact rate control is achieved by the selection of the parts of each code-block to be contained in the final code-stream. The code-block bit-stream may be truncated at a certain point. An optimal rate control process called PCRD is utilized in the standard. This process is summarized as follows.

It assumes that n_i denotes the feasible truncation points (TP) of the ith code-block. Each code-block bit-stream can be truncated at any feasible TP resulting in bit rate $R_i^{n_i}$ and the corresponding distortion is denoted by $D_i^{n_i}$ which is produced by reconstructing the truncated bit-stream. The final goal of rate control is to allocate the target bit rate into an image such that the overall distortion D can be minimized as follows.

$$\begin{cases} \min \sum_i D_i^{n_i} \\ \sum_i R_i^{n_i} = R_{\text{target}} \end{cases} \tag{2}$$

where R_{target} represents the target bit rate. Using the Lagrange multiplier method the optimization process is equivalent to minimize the bellow equation:

$$L = D + \lambda R = \sum_i (D_i^{n_i} + \lambda R_i^{n_i}) \tag{3}$$

If we can find a value of λ such that the resulting set of truncation points minimizes Eq. (3) and produces R=R_{target}, the value of λ and the set of TP will be optimal. In other words the result with solution of Eq. (4) is as follows:

$$\begin{cases} \dfrac{\partial D_i^{n_i}}{\partial R_i^{n_i}} = \dfrac{\Delta D_i^{n_i}}{\Delta R_i^{n_i}} = \lambda \\ \sum_i R_i^{n_i} \le R_{\text{target}} \end{cases} \tag{4}$$

PCRD is a simple but high-complexity algorithm to find the optimal truncation points. At any feasible truncation point (for example at the end of each coding pass) PCRD computes the rate distortion slope which is determined as

$$S_i^{n_i} = \frac{\Delta D_i^{n_i}}{\Delta R_i^{n_i}} = \frac{D_i^{n_i-1} - D_i^{n_i}}{R_i^{n_i} - R_i^{n_i-1}} \tag{5}$$

The PCRD algorithm is as follows:

1) Set N_i={n}, i.e. the set of all candidate truncation points
2) Set p=0
3) For k=1, 2, 3, 4, ⋯, ∞
 If k belongs to N_i
  Set $\Delta R_i^k = R_i^k - R_i^p$ and $\Delta D_i^k = D_i^p - D_i^k$
  Set $S_i^k = \dfrac{\Delta D_i^k}{\Delta R_i^k}$
 If p≠0 and $S_i^k \rangle S_i^p$ then remove p from N_i and go to Step 2)
 Otherwise, set p=k

Above algorithm requires that encoding all coding passes even a large contribution of them will not be contained in the final code-stream. Tier-1 encoding in the JPEG2000 standard is complex.

3 Proposed rate control method

In this research, allow-complexity rate distortion method for JPEG2000 is proposed. It is relied on a reverse order for sub-bands and coding passes. The proposed algorithm avoids encoding all coding passes and encodes only the coding passes contained in the final code-stream and it does not need any post compression rate control part. As mentioned before, the CPI strategy selects the coding passes included in the output code-stream using a simple scanning order based on the significance levels (SL). The sub bit-plane coder in JPEG2000 standard encodes each bit in three passes called SPP, MRP and CP. The significance level of a code-block is achieved by SL=(bit plane×3)+CoP Type where CoP Type={SPP=2, MRP=1, CP=0}.

In the CPI algorithm, assume that a coding pass which belongs to a higher SL has a very high probability to be included in the final code-stream, thus is distinguished between coding passes which belongs to a higher SL and lower SL.CPI scans coding passes of all code blocks situated at the same SL, from the highest SL to the lowest SL until the bit rate reaches to be equal to or more than the target bit rate. In each SL, the passes are chosen from the lowest resolution level (LRL) to the highest resolution level (HRL), beginning at the LL sub-band and then the HL, LH, HH sub-bands respectively. CPI does not need any post compression rate control stage. The scanning order used by CPI is the same used in other coding schemes. The results obtained by them are regular for all the bitrates.

It may be expected that the performance of CPI should be similar to other coding schemes, but the performance of CPI is not regular for all the bitrates. The performance of CPI at the different bit rates is less than the PCRD method for peak signal-to-noise ratio parameter. It is not a regular manner. This difference at the low bitrates is more than the high bitrates. Both CPI and PCRD methods choice the same coding passes, when CPI ends the scanning of a SL that includes coding passes of type SPP or at the end of a SL that includes coding passes of type CP.

Therefore, this question appears why these differences are generated. In this research the mean square error is used as the distortion standard which computes the distortion contribution of all resolution levels at each of the SL. With survey of the relationship's distortion, it is clear that the distortion contribution of the higher resolution levels for lower SLs is more than the distortion contribution of the lower resolution levels. In this research the coding order is reversed for the resolution levels and the coding passes.

The coding order for resolution levels performs from the highest level to the lowest level, in addition to the coding order performs for the MRP passes and the CP passes as follows: HH, LH, HL. When the percentage of target of the code-blocks belonging to the highest resolution level is contained in the SL, the coding order is reversed for the resolution levels and the coding passes as mentioned. The proposed algorithm avoids encoding all coding passes and encodes only the coding passes contained in the final code-stream and it does not need any post compression rate control stage. The computational complexity of proposed algorithm is negligible, making it suitable to compression and attaining a significant performance. The block diagram of proposed method is illustrated in Fig. 1.

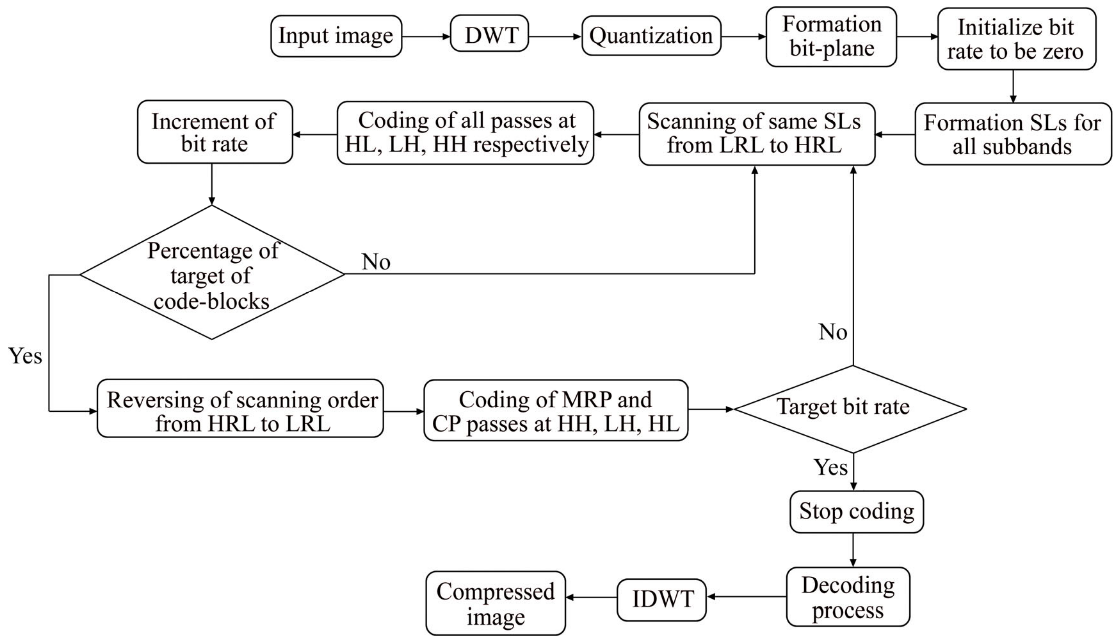

Fig. 1 Block diagram of proposed method

4 Experimental results

The proposed algorithm is simulated on the Matlab software. Our method is tested on different test images about which only we discus, Lena (512×512), Peppers (512×512) and Airplane (512×512). The type of the wavelet transform is 9/7 and the code block size is 64 pixel×64 pixel.

The experimental results for the PSNR parameter are compared with those by the PCRD algorithm and are shown in Table 1, where F is the PCRD algorithm and E is the proposed algorithm.

Table 1 PSNR comparison of proposed method and PCRD algorithm

Algorithm	PSNR/dB				Image
	2.0 bpp	1.5 bpp	1.0 bpp	0.5 bpp	
E	43.80	42.96	37.25	36.20	Lena
	46.09	42.14	35.05	27.92	Airplane
	43.03	38.71	36.83	35.99	Pepper
F	36.278	36.296	33.136	30.163	Lena
	36.40	35.333	32.973	30.107	Airplane
	32.629	28.789	26.169	24.195	Pepper
Mean difference	9.3	7.6	5.6	7.5	

At different bit rates for Lena image, the PSNR of the proposed algorithm decreases negligibly and for another images the performance of the proposed method is better than the PCRD. The experimental results in terms of PSNR are compared with those by the HERC algorithm [13] and are shown in Table 2, where F is the HERC algorithm and E is the proposed algorithm. The PSNR of the proposed algorithm is more than the HERC algorithm for all bit rates. The proposed method can achieve good results while its complexity is negligible since reverse order is utilized for the resolution levels and the coding passes and encoding all coding passes is avoided. The PSNR values at the different bitrates for the proposed algorithm, the HERC algorithm and the PCRD algorithm for Lena (512×512) are shown in Fig. 2(a). The PSNR values achieved by the proposed algorithm are more than those by the HERC algorithm.

However, the PSNR of the proposed algorithm is less than that of the PCRD algorithm; the difference is small and the differences at the bit rates of 1.5 bpp and 2.0 bpp are negligible.

However, the PSNR of the proposed algorithm is less than that of the PCRD algorithm; the difference is small and the differences at the bit rates of 1.5 bpp and 2.0 bpp are negligible. The PSNR values achieved by the proposed algorithm are more than those by the HERC algorithm. The visual quality of the compressed images of the Lena by the proposed algorithm, the HERC algorithm [13], the PMSD algorithm [22] and the PCRD algorithm at the bit rate of 0.5 bpp is illustrated in Figs. 2(b)−(f).

Table 2 PSNR comparison of proposed method and HERC algorithm

Algorithm	PSNR/dB				Image
	2.0 bpp	1.5 bpp	1.0 bpp	0.5 bpp	
E	43.80	42.96	37.25	36.20	Lena
	46.09	42.14	35.05	27.92	Airplane
	43.03	38.71	36.83	35.99	Pepper
F	35.577	35.998	32.93	30.124	Lena
	37.700	34.865	32.959	26.95	Airplane
	32.496	28.135	26.088	24.04	Pepper
Mean difference	9.33	8.33	6	5.33	

However, the PSNR of the proposed method is less than that of the PCRD algorithm and the difference in the image visual quality is negligible. The PSNR of the proposed method is better than that of the HERC algorithm and for the PSNR, the PMSD method is similar to the PCRD algorithm. Therefore, the proposed algorithm can achieve the desirable quality, while the computations complexity is reduced.

The PSNR values at the different bit rates for the HERC algorithm, the PCRD algorithm and the proposed algorithm, for Peppers image are illustrated in Fig. 3(a). The PSNR values achieved by the proposed algorithm are more than both of the algorithms, the HERC algorithm and PCRD algorithm. The good results are achieved while encoding all coding passes is avoided, only the coding passes contained in the final code-stream are encoded and the computational complexity is negligible.

The PSNR values achieved by the proposed algorithm are more than both of the mentioned algorithms. The visual quality of the compressed images of the peppers image by using the proposed algorithm at the different bit rates is shown in Figs. 3(b)−(e). The proposed algorithm can achieve the good visual quality at the different bit rates, while the computations complexity is less than that of PCRD algorithm.

The PSNR values at the different bit rates for two modes, with applying reverse order (RO) and another without applying reverse order for Lena image are illustrated in Fig. 4(a). The PSNR values achieved by the mode of applying reverse order are more than those by the mode of without applying reverse order.

The visual quality of the compressed images of the

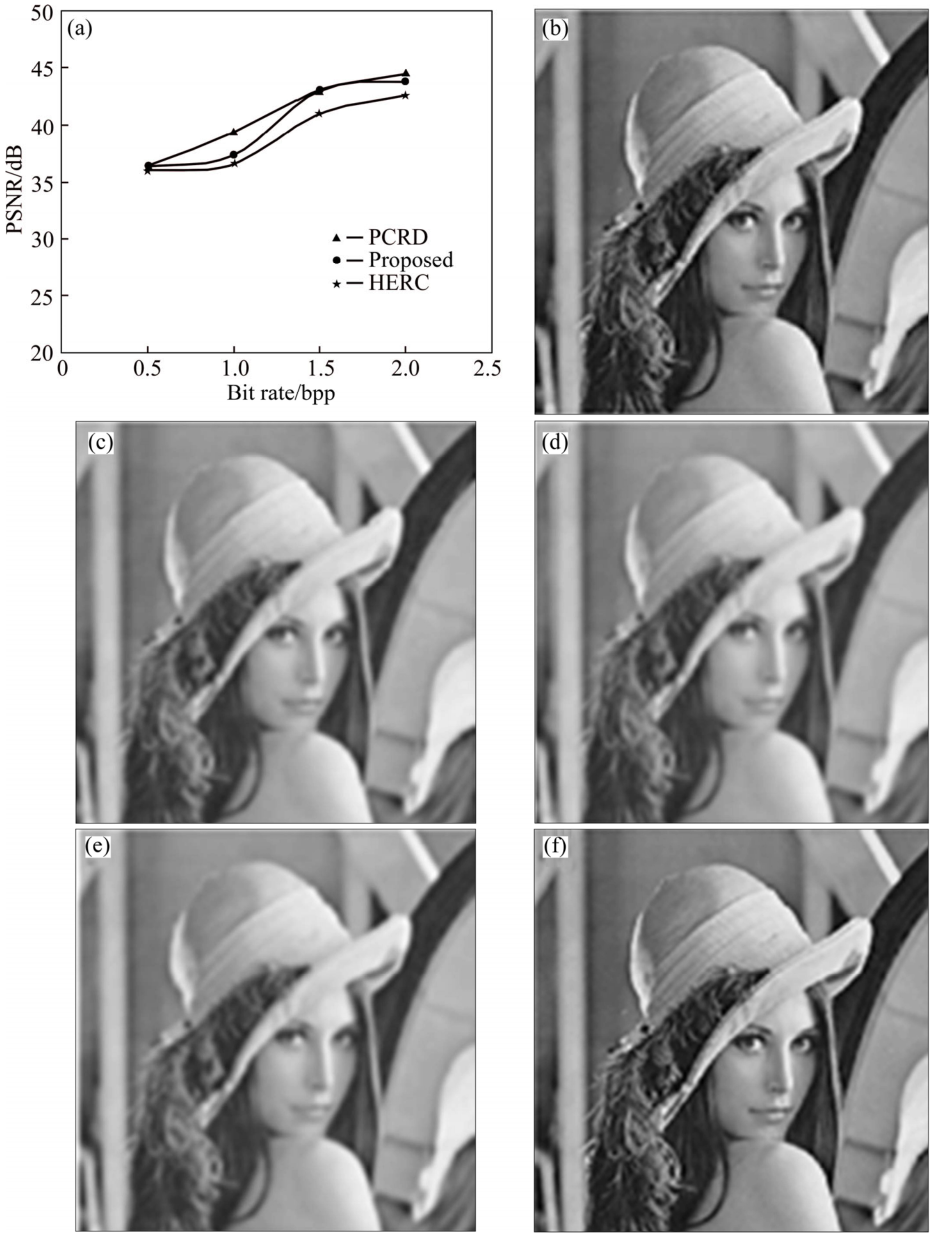

Fig. 2 PSNR values for Lena (a) and visual quality of Lena by different algorithms at bit rate of 0.5 bpp: (b) Original; (c) PCRD algorithm; (d) HERC algorithm; (e) PMSD algorithm; (f) Proposed algorithm

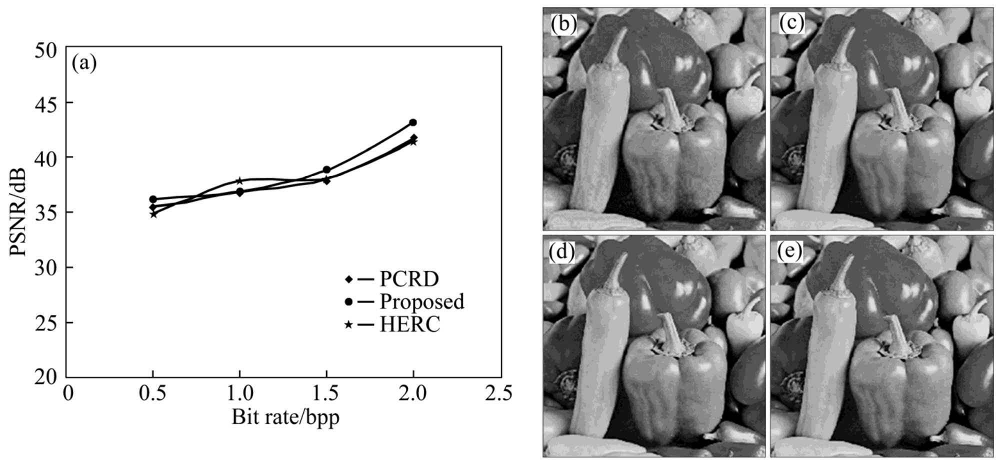

Fig. 3 PSNR values for Peppers (a) and visual quality of Peppers image by proposed algorithm: (b) 0.5 bpp, PSNR 35.9979; (c) 1.0 bpp, PSNR 36.8394; (d) 1.5 bpp, PSNR 38.7199; (e) 2.0 bpp, PSNR 43.0331

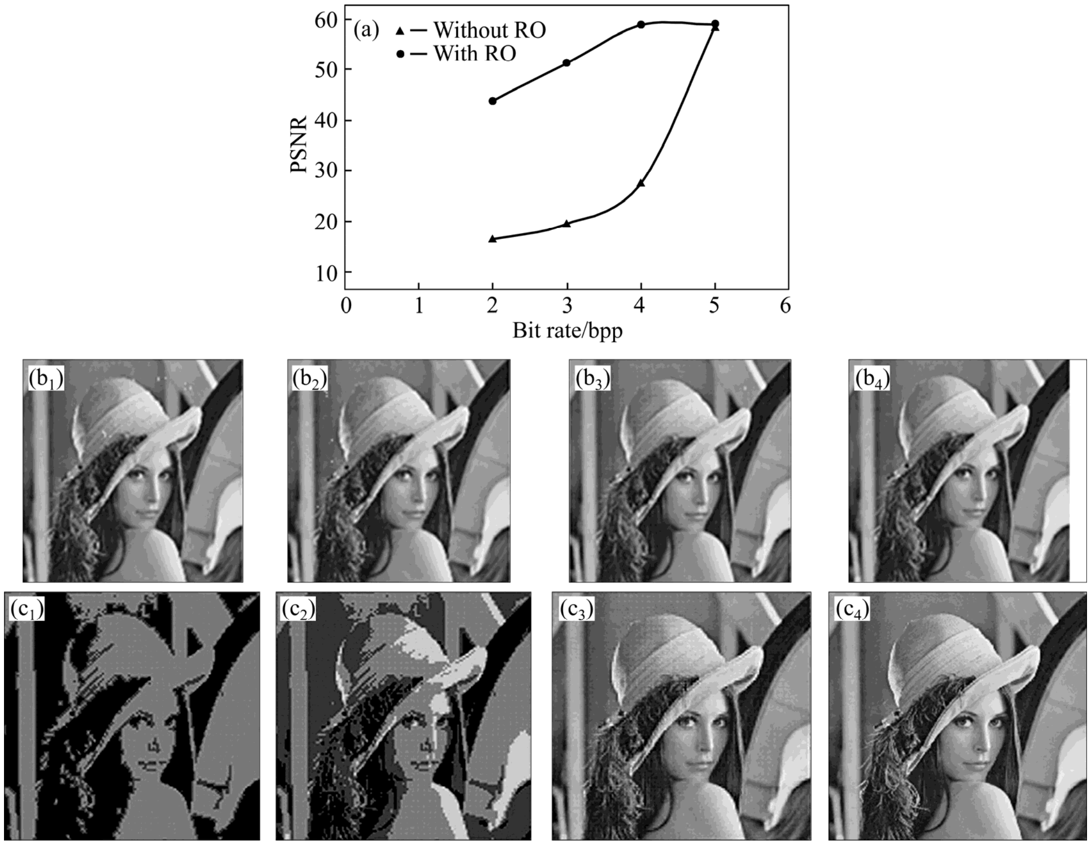

Fig. 4 PSNR values visual quality of Lena image with applying reverse order (b) and without applying reverse order (c): (b_1) Bit rate=2.0 bpp, PSNR 43.8069; (b_2) Bit rate=3.0 bpp, PSNR 51.2523; (b_3) Bit rate=4.0 bpp, PSNR 58.7207; (b_4) Bit rate=5.0 bpp, PSNR 58.7207; (c_1) Bit rate=2.0 bpp, PSNR 12.3126; (c_2) Bit rate=3.0 bpp, PSNR 16.3693; (c_3) Bit rate=4.0 bpp, PSNR 26.5672; (c_4) Bit rate=5.0 bpp, PSNR 45.4124

Lena for two modes, with applying reverse order (RO) and another without applying reverse order is illustrated in Figs. 4(b) and (c).

The PSNR values at the different bit rates for two modes, with applying reverse order and another without applying reverse order for woman image are shown in Fig. 5(a). The PSNR values achieved by the mode of applying reverse order are more than those by the mode of without applying reverse order.

The visual quality of the compressed images of the woman for two modes with applying reverse order and another without applying reverse order is illustrated in Figs. 5(b) and (c).

The PSNR values at the different bit rates for two modes, with applying reverse order (RO) and another without applying reverse order for Baboon image are illustrated in Fig. 6(a). The PSNR values achieved by the mode of applying reverse order are more than those by the mode of without applying reverse order. The differences between two mentioned modes at all bit rates are significant.

The visual quality of the compressed images of the Baboon for two modes, with applying reverse order and another without applying reverse order is illustrated in Figs. 6(b) and (c). The mode of reverse order can achieve the good visual quality at the different bit rates, while the computations complexity is negligible.

The PSNR values at the different bit rates for two modes, with applying reverse order and another without applying reverse order for boat image are illustrated in Fig. 7(a).

The PSNR values achieved by the mode of applying reverse order are more than those by the mode of without applying reverse order. The visual quality of the compressed images of the boat for two modes, with applying reverse order and another without applying reverse order is illustrated in Figs. 7(b) and (c).

The PSNR values at the different bit rates for two modes, with applying reverse order (RO) and another without applying reverse order for airplane image are illustrated in Fig. 8(a). The PSNR values achieved by the mode of applying reverse order are more than those by the mode of without applying reverse order.

The visual quality of the compressed images of the airplane for two modes, with applying reverse order and another without applying reverse order is illustrated in Figs. 8(b) and (c).

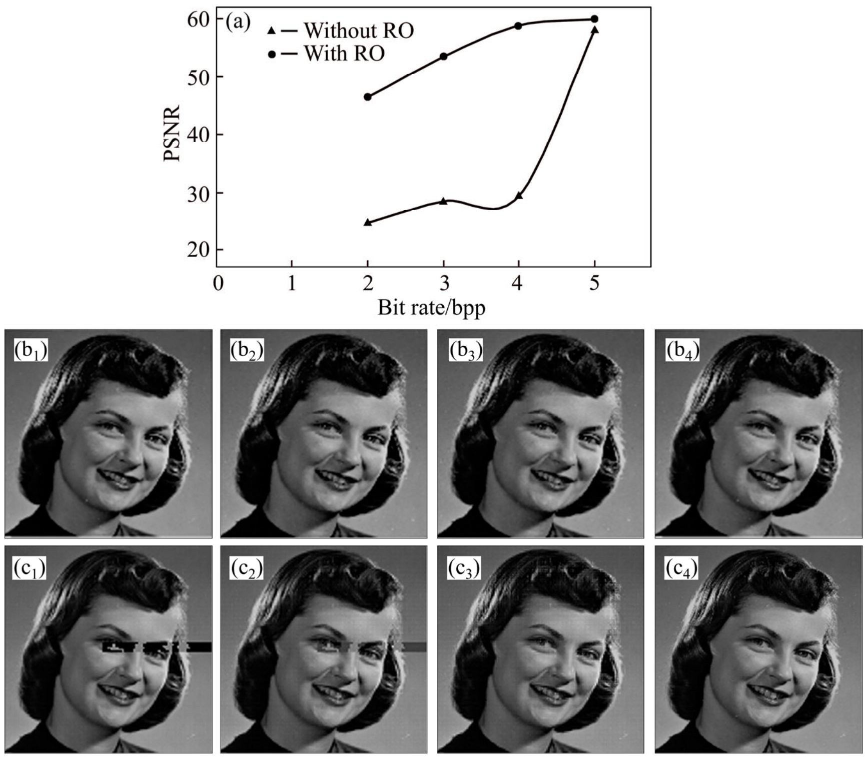

Fig. 5 PSNR values for Woman (a) and visual quality of Woman images with applying reverse order (b) and without applying reverse order (c): (b_1) Bit rate=2.0 bpp, PSNR 46.3296; (b_2) Bit rate=3.0 bpp, PSNR 53.4016; (b_3) Bit rate=4.0 bpp, PSNR 58.7695; (b_4) Bit rate=5.0 bpp, PSNR 58.7695; (c_1) Bit rate=2.0 bpp, PSNR 24.7099; (c_2) Bit rate=3.0 bpp, PSNR 28.4317; (c_3) Bit rate=4.0 bpp, PSNR 28.4628; (c_4) Bit rate=5.0 bpp, PSNR 58.1111

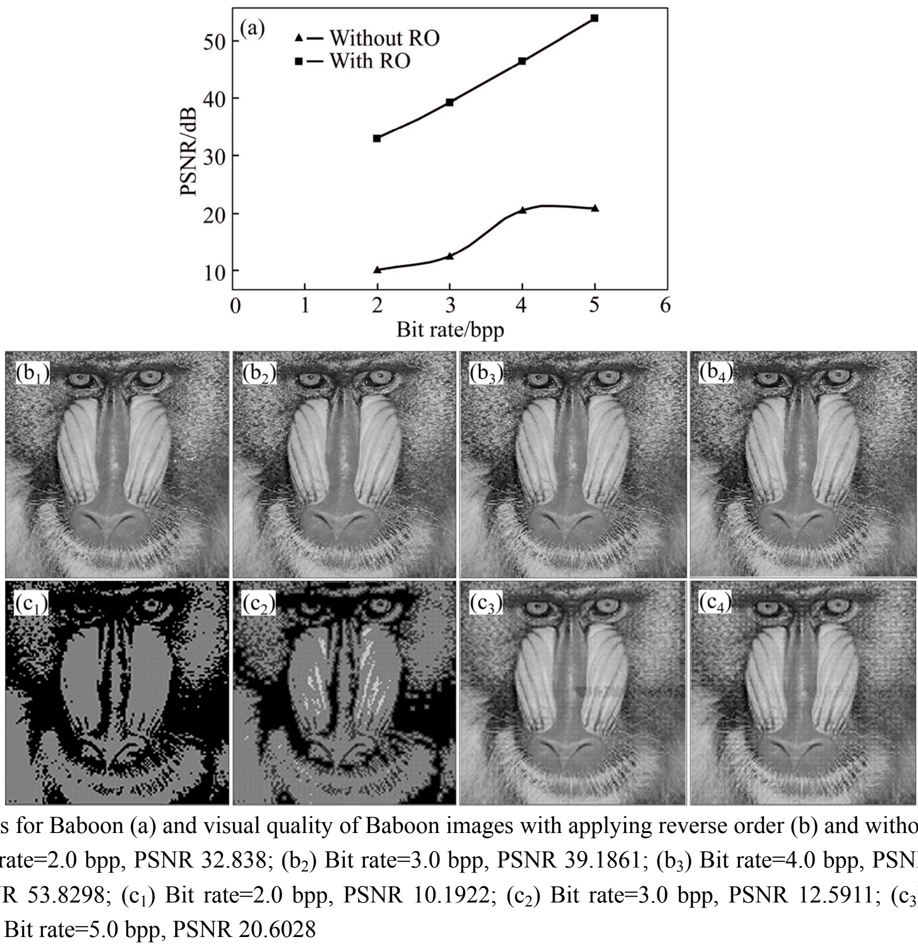

Fig. 6 PSNR values for Baboon (a) and visual quality of Baboon images with applying reverse order (b) and without applying reverse order (b): (b_1) Bit rate=2.0 bpp, PSNR 32.838; (b_2) Bit rate=3.0 bpp, PSNR 39.1861; (b_3) Bit rate=4.0 bpp, PSNR 46.4752; (b_4) Bit rate=5.0 bpp, PSNR 53.8298; (c_1) Bit rate=2.0 bpp, PSNR 10.1922; (c_2) Bit rate=3.0 bpp, PSNR 12.5911; (c_3) Bit rate=4.0 bpp, PSNR 20.961; (c_4) Bit rate=5.0 bpp, PSNR 20.6028

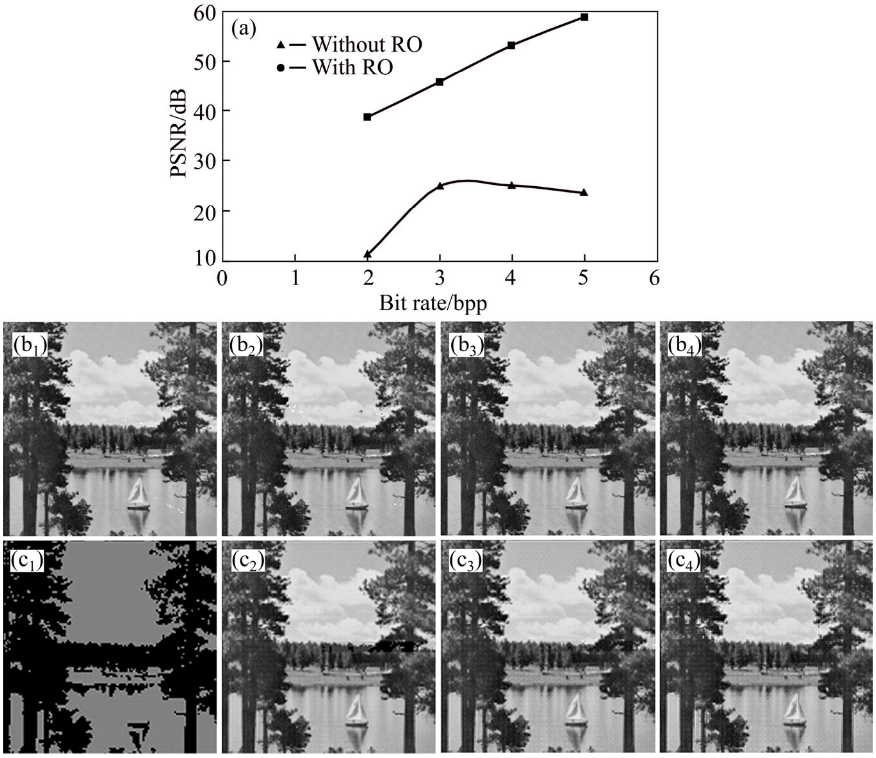

Fig. 7 PSNR values for Boat (a) and visual quality of Boat images with applying reverse order (b) and without applying reverse order (c): (b_1) Bit rate=2.0 bpp, PSNR 38.7481; (b_2) Bit rate=3.0 bpp, PSNR 45.8682; (b_3) Bit rate=4.0 bpp, PSNR 53.1981; (b_4) Bit rate=5.0 bpp, PSNR 58.7106; (c_1) Bit rate=2.0 bpp, PSNR 11.2489; (c_2) Bit rate=3.0 bpp, PSNR 24.957; (c_3) Bit rate=4.0 bpp, PSNR 25.0683; (c_4) Bit rate=5.0 bpp, PSNR 23.66

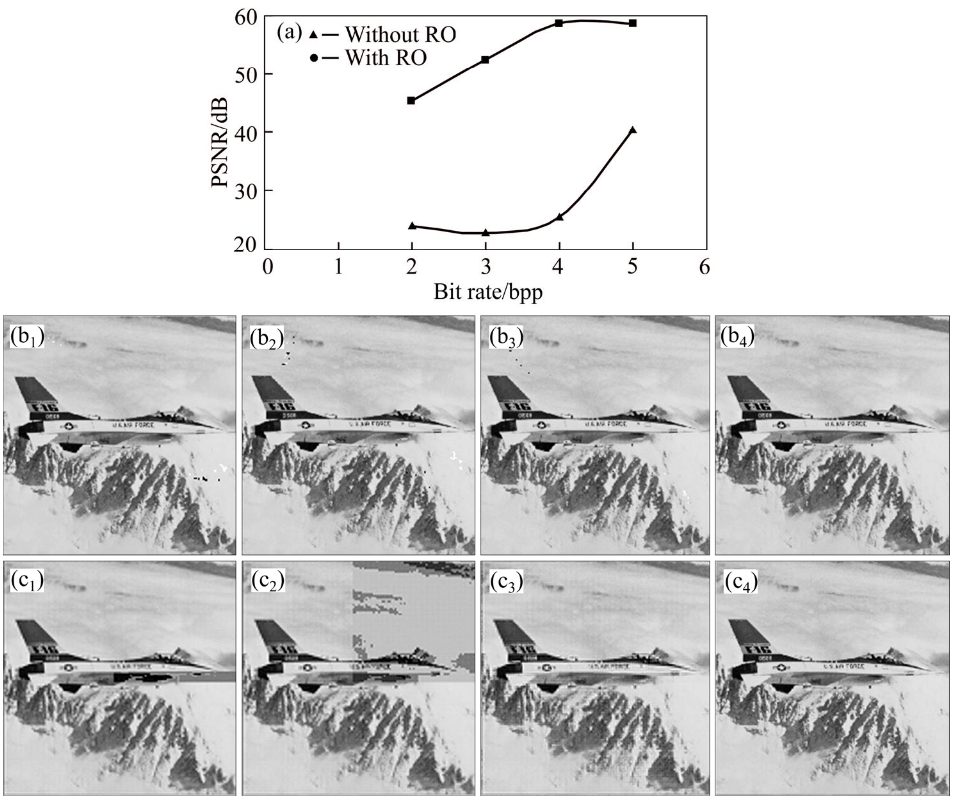

Fig. 8 PSNR values for Airplane (a) and visual quality of Airplane images with applying reverse order (b) and without applying reverse order (c): (b_1) Bit rate=2.0 bpp, PSNR 45.3726; (b_2) Bit rate=3.0 bpp, PSNR 52.4305; (b_3) Bit rate=4.0 bpp, PSNR 58.6555; (b_4) Bit rate=5.0 bpp, PSNR 58.6555; (c_1) Bit rate=2.0 bpp, PSNR 24.0332; (c_2) Bit rate=3.0 bpp, PSNR 22.8072; (c_3) Bit rate=4.0 bpp, PSNR 25.5503; (c_4) Bit rate=5.0 bpp, PSNR 40.4848

5 Conclusions

In this research, an efficient rate control algorithm for JPEG2000 has been presented. Since the PCRD algorithm requires encoding all the coding passes, most of the computation and working memory could be weighed redundant. The proposed method is relied on a reverse order for the resolution levels and the coding passes in the CPI algorithm. When the percentage of target of the code-blocks belonging to the highest resolution level is contained in the SL, the coding order is reversed for the resolution levels and the coding passes. The proposed algorithm avoids encoding all coding passes, encodes only the coding passes contained in the final code-stream and it does not need any post compression rate control part. The computational complexity of proposed algorithm is negligible, making it suitable to compression and attaining a significant performance. Simulation results show that the PSNR values by obtained the proposed algorithm are comparable with the optimal PCRD. The PSNR values achieved by the mode of applying reverse order are more than those by the mode without applying reverse order.

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