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A Rate Control Algorithm in JPEG2000 Based on Code Content Prediction

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Abstract

In order to accelerate the coding process of JPEG2000 and avoid encoding useless codes, a new algorithm is proposed for JPEG2000 rate control. This algorithm is improved by the model prediction algorithm. The code passes transmit the lowest frequency sub-band without distortion after wavelet decomposition. Then the proposed algorithm allocates the rate for the current code block accords to the number of coding passes and the weight of wavelet quantization. At last, it encodes the code block which brings the greatest amount of information preferentially, according to the code block bit-plane relationship in the sub-band; In addition, the algorithm truncates the code-stream in real time during the encoding procedure. Compared with the PCRD algorithm, the experimental results indicate that the proposed algorithm can greatly reduce the computation operation and encoding time.

Keywords: *post-compression rate-distortion (PCRD) optimization, embedded block coding with optimized truncation (EBCOT), JPEG2000*

1. Introduction

JPEG2000's algorithm is based on the Discrete Wavelet Transform (DWT) and the Embedded Block Coding with Optimal Truncation (EBCOT). It has better compression performance and new functionalities, it not only can keep a higher compresion ratio and a lower bit rate and encode the region of interest, achieve progressive transmission of bit stream, but also access to bit stream randomly. Since JPEG2000 has excellent performance, it has been widely used in areas such as network video transmission, wireless communications, medical images and image retrieval [1].

The EBCOT algorithm comprises two stages which are called Tier1 encoding and Tier2 encoding [11]. Tier1 encodes the bit-plane and generates the code word; Tier2 codeword accords the rate control algorithm to truncate the bit stream to form the output stream. The rate control algorithm in the Tier2 need to truncate the stream and discard the codeword, which has little contribution to image quality. The Tier1 codeword may be discarded in the Tier2 encoding, which will result in storage space wasting and redundancy computing. Numerous researchers have proposed a variety of improved rate control algorithms. These rate control methods can be divided into two classes: one is optimal calculation based on the rate distortion slope; the other is based on models and prediction algorithm [10]. Rate distortion slope optimization algorithm is a kind of calculating method by changing the slope value [5]. This kind of rate control algorithms are just to simplify the calculation of rate distortion slope, but they cannot achieve real-time truncating stream, so the coding efficiency is not high [7]. The models and prediction algorithm dosn't require the calculation of the rate-distortion slope.The algorithm distributes bit rate to each code block or pass, by training appropriate encode models,or accord to the properties of image. This algorithm is simpler, but the model prediction error is larger, and the image PSNR (peak signal-to-noise ratio) drops more seriously.

In this paper, a rate control algorithm based on code content prediction was proposed. Taking advantage of the characteristics of the energy concentration after the wavelet decomposition, it transfers the lowest frequency subband without distortion; And distribute the encode bit stream to the remaining subband accord to the characteristics of subband's coefficient. In the entropy coding, the algorithm selects the code block which brings the maximum information and encode it preferentially. The algorithm improves the performance of

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the image, and overcomes the shortcomings that the model prediction algorithm error is too large.

2. The Traditional PCRD Algorithm in JPEG2000

The JPEG2000 standar recommends to utilize the post compress rate distortion optimal algorithm, the main principle is: When the bit rate value is determined, find a optimal truncation point to minimize the distortion [3].

In the EBCOT algorithm, each code block is encoded independently. In addition, its wavelet transformation is orthogonal [2], so that code blocks on reconstructed image distortion are irrelevant.

The total distortion is:

$$D = \sum_i D_i^{n_i} \tag{1}$$

That is, the distortion, $D_i^{n_i}$ for the Bi code block at the ni truncation point is given by Equation (1) [10].

The total bit rate of image is:

$$R = \sum_i R_i^{n_i} \tag{2}$$

That is, the rate for the B_i code block at the n_i truncation point R_i is defined by equation (2).

The significant properties of the R-D slope are: (1) the slope values of truncation points in code block are monotonically decreasing; (2) the slope value of high-bit-plane is larger than the value of the slope of the low-bit-plane; (3) the slope value of the earlier encoded pass is greater than the later one in the same bit plane [6].

The purpose of Rate-Distortion optimization is looking for a truncation point set $\{n_i\}$ under the condition of $R \le R_{max}$ to minimize the total distortion D [4]. This can be accomplished by calculating the slope with respect to distortion vs rate of the current truncation point with respect to the next truncation point. Where the slope, is equal to the change in respective distortion vs the change in respective rate. Once the feasible truncation points have been selected, a slope will be selected and all code blocks are truncated at the truncation point which most closely matches this slope. Then the total rate of the final file is calculated, if the anticipated rate isn't reached, then a new slope will be selected and the process will repeat. When the rate requirement is satisfied, the code blocks are truncated at their respective truncation point.

The algorithm process of looking for the truncation point set of decreasing rate-distortion slope is as follows:

do
{ N_i ={n}
P=0
for k= 1 to j
{if k $\in N_i$
{
$\Delta D_{i,k} = D_{i,p} - D_{i,k}$
$\Delta R_{i,k} = R_{i,k} - D_{i,p}$
$S_{i,k} = \Delta D_{i,k} / \Delta R_{i,k}$
}
if (p ≠0 and $S_{i,k} > S_{i,p}$)
p is removed from the set{ N_i }
else p = k
}
}

Wavelet transformation provides a multi-resolution representation with various desirable properties [8], e.g. subband decomposition with orientation selectivity, self similarity of wavelet coefficients across subbands of the same orientation, and energy clustering within each subband. And the subband of LL has more energy than the subband of LH and HL, while the HH subband has the least energy. In decoding process, the subband of LL gives the most contribution to the image while the subband of HH gives the least contribution to the image. Therefore, the proposed algorithm discards the high frequency subband to obtain a superior image compression performance.

3. Rate Control Algorithm based on the Coding Content Prediction
3.1. Prediction Method

Image after wavelet transformation, the lowest frequency sub-band carrys a lot of image information. Therefore, it can transfer the lowest frequency subband without distortion. So the remaining rate is the total rate minus the rate of LL. The proposed algorithm distributes the remaining rate to the remaining subband according to the characteristics of subband's coefficient [9]. Different subbands have different contributions to the quality of image after wavelet transformation, which determined by the importance of the quantization step and the weight of the wavelet subbands.

The weighting coefficients of the different subbands are given by $\omega\Delta^2$, a quantization step, Δ the wavelet subband norm, ω.

As is shown in the Figure 1(a), the order of scanning and encoding the sub-band is from the lowest sub-band to the highest one. When encoding code block in the same subband, it utilizes the same quantization step, as a result of that,the order of scanning and encoding code block in sub-band is shown in Figure 1(b). When truncating the coding, the code block information in the largest bit plane may be discarded and leads to the coding efficiency failed to achieve a maximum value. Therefore, according to the level of bit plane, a new coding order comes out: coding the bit plane from the highest one to the lowest one in turn, it can ensure the coding keeps a high efficiency.

(a) The scanning order of sub-band (b) The scanning order of code block in sub-band

Figure 1. The Order of Scanning

The maximum bit plane of code block B_i is calculated by Equation (3).

$$numbps_i = \log_2 [\max_{(m,n)} |q_i(m,n)|] \quad (3)$$

The number of encoding passes is calculated by Equation (4).

$$P^i = 3*numbps_i - 2 \quad (4)$$

The maximum bit plane of the subband is calculated by Equation (5).

$$bps_j = \max_j \{numbps_i\} \quad (5)$$

3.2. The Algorithm Flow

The implementation process is as follows: the code passes transfer the lowest subband without distortion, then distribute the remaining encode bit streams to the remaining subband accord to the significance of wavelet sub-band and the number of sub-band passes. In the sub-band, according to the number of passes in each code block vs the total pasess of the subband, distributes the appropriate number of bit streams to each code block. When the accumulated encoded bit streams are greater than the allocated bit streams, cease to encode. Calculating rate-distortion slope for each pass and accumulating total compressed bit streams.When each subband's coding is finished, updates the allocated bit streams of the subband. When the total cumulative encoded bit streams are greater than the target bit stream, and if there is subband still havn't been encoded, change the allocation strategy. Distributing bit streams to the uncoded subband, until all the sub-band's coding is completed.

(1) Calculate the number of bit streams of the LL subband R_0. The weighting coefficient of the subband j is $\overline{\omega_j} = \frac{\omega_j \Delta_j^2}{A} \times (j+1)$, where A is the $\sum_{k=3r-j}^{3r} \omega_k \Delta_k^2$, the wavelet subband L_2 norm, ω, a quantization step, △ r is the wavelet decomposition levels, j is from 1 to 3*r; Calculate the number of encoded passes in the subband j is $P_j = \sum_i p^i$; Calculate the total number of encoded passes except the lowest subband is $P_{total} = \sum_{j=1}^{3r} P_j$.

(2) Calculate the remaining number of encoded bit streams $R_{allot}=R_{target}-R_0$, where R_{target} is the target number of bit streams of the current tile.

(3) Initial the cumulative number of bit streams of the subband, sub_sum=0, shift=0;

(4) The total number of encoded bit streams which has been distributed is Rallot=(Rtarget-R0)/(++shift).

(5) Distribute the appropriate number of bit streams to each subband, according to the number of passes in each subband and the subband's coefficient. The number of bit streams is distributed in the subband j is $R_{allot}^j = [R_{allot} \times \omega_j \times P_j / P_{total}]$.

Distribute the appropriate number of bit streams to each code block, according to the number of passes in each code block vs the total pasess of the subband. The number of bit streams that is distributed in the code block B_i^j is $R_i^j = [R_{allot} \times \omega_j \times P_j^i / P_{total}]$. Initial the cumulative number of bit streams of the current subband, sub_sum R_j=0.

(6) Calculate the maximum bit plane of code block B_i in the subband j. The judgment of the code block maximum bit plane is equal to the subband bit plane , $numbps_i = bps_j$, if it is yes, go to (7); if not, calculate the maximum bit plane of the next code block in the subband j, until the last code block, go to (8).

(7) When the cumulative encoding bit streams of code block is larger than the distributed bit streams, sum $R_i^j > R_i^j$, or the pass coding is completed, pause to encode the current code block, and go to (6), encode the next code block. The cumulative number of bit streams of the current subband is sub_sum = sub_sum + sum;

(8) After the all numbpsi=bpsj code blocks' coding have been done, the bps_j should be equal to the bps_j-1, The judgment of the cumulative encoding bit streams of the current subband is larger than the distributed subband encoding bit streams, sub_sum $R^j > R_{allot}^j$, if it is yes, go to (9); if not, Continue encoding.

(9) Search the minimum rate distortion slope in the already encoded pass, and utilize the cumulative encoding bit streams sub_sum R^j minus the encoded bit streams that has the minimum slope. Until it meets the conditions of sub_sum $R^j < R_{allot}^j$, then go to (10).

(10) When the cumulative encoding bit streams of all code blocks is smaller than the distriuted bit streams, or the all code blocks have completed their pass coding, then go to (11); if not go to (8).

(11) If all subband encoding have been completed, pause to encode, truncate the encoded bit streams and accumulate the number of encoded bit streams sub_sum R = sub_sum R + sub_sum R^j. If not, go to (3).

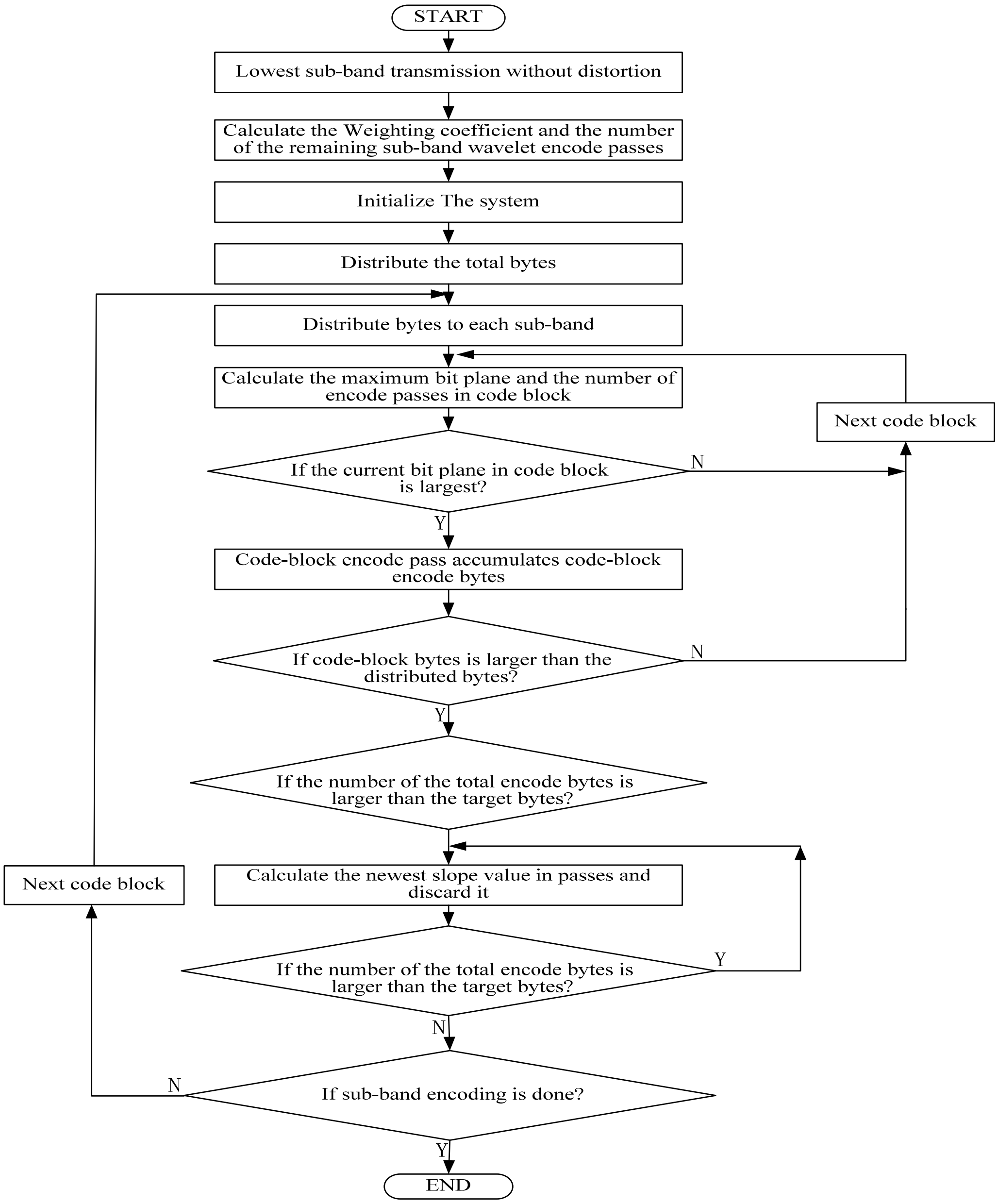

Figure 2. The Flowchart of Algorithm

4. Analysis and Comparison of the Experimental Results

The proposed algorithm is applied in the Jasper software, which is recommended by the JPEG2000 standard. Table 1 is the comparison results of PSNR that contains the proposed algorithm, literature 7 and the PCRD algorithm (Jaser1.900.1). Three standard test images lena, goldhill and airplane were carried out experiments, the image size is 512×512, the size of code block is 32×32. Figure 5 demonstrates the comparison that images are compressed under the conditions of the compression ratio is 1:100.

Table 1 points out that the proposed algorithm has the same image quality, compared with the PCRD algorithm, no matter it utilized a high compression ratio or a low one, the average PSNR difference is still less than 0.5dB. While the above two algorithms compare to the literature 7, the PSNR has magnified. Specially, the PSNR of the image airplane improved obviously as is shown in Figure 4. The proposed algorithm overcomes the shortcoming that the model prediction algorithm’s error is large. In Figure 3, nobody can distinguish the difference from the pictures that compressed by the proposed algorithm and the PCRD algorithm.

Table 1. The PSNR Performance Comparison of the Proposed, the Literature 7 and PCRD Algorithm

PSNR / Image	Compression Ratio	10	20	25	50	80	100
Lena	PCRD	37.23	34.02	33.00	30.14	28.41	27.57
	proposed	36.91	33.81	32.76	29.98	28.35	27.54
	literatur7	36.51	33.42	32.22	29.78	28.26	27.32
goldhill	PCRD	34.70	31.65	30.88	28.60	27.33	26.73
	proposed	34.41	31.39	30.76	28.36	26.97	26.54
	literature7	34.40	31.31	30.69	28.23	26.78	26.31
Airplane	PCRD	45.71	41.05	39.56	34.93	32.17	21.36
	proposed	45.53	40.94	39.33	34.73	31.82	21.21
	literature7	43.70	38.60	36.76	31.31	28.94	20.37

(a) The original image (b) The PCRD algorithm (c) The proposed algorithm

Figure 3. The Image Comparison of Different Algorithm

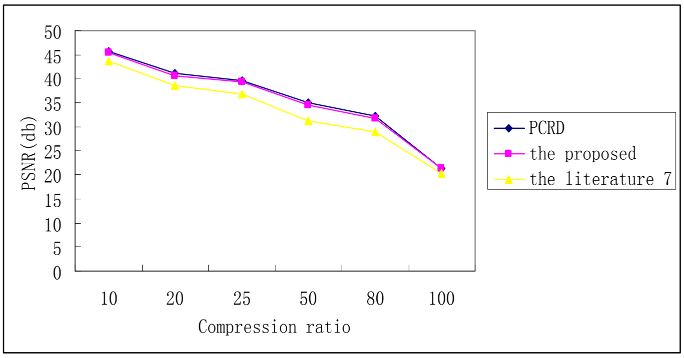

Figure 4. PSNR Performance Comparison of Airplane

The traditional PCRD algorithm always encodes all the code blocks preferentially, and then packages to form output stream, no matter how much the bit rate is. So they have the same number of the code passes, when they are compressed at different compression ratios. In this paper the algorithm truncates the code pass in real time, so that the number of code passes increases with the rate gets larger.

In Figure 5, the proposed algorithm reduces the number of encoded passes, compared with the PCRD algorithm. When the compression ratio is large, the proposed algorithm can save more than 80% of the encode passes. This can reduce the intermediate data storage and save a lot of coding time.

Encoding the image of Lena with three different algorithms, we found that the proposed algorithm's computing time was 80% shorter than the PCRD algorithm, while it was the same as the literature 7 algorithm.

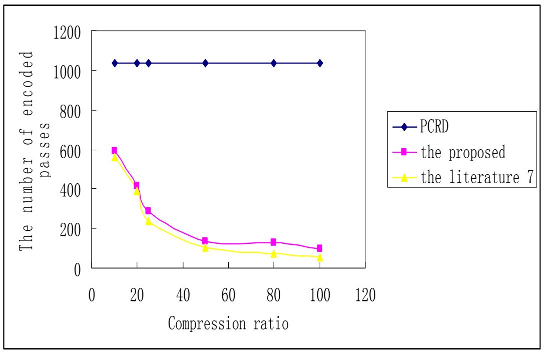

Figure 5. Encoded Pass Comparison of Different Compression Ratio

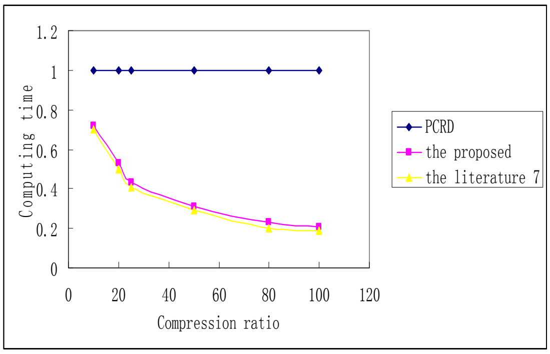

Figure 6. Encoded Time of Different Compression Ratio

5. Conclusion

In this paper, we proposed a rate control algorithm that based on code content prediction. It transfers the lowest frequency subband without distortion, taking advantage of the characteristics of the energy is concentrated in low frequency sub-band after the wavelet decomposition. In the entropy coding, select the code block that brings the maximum information and encode it preferentially. It ensures the image have a high quality, and overcomes the shortcoming that the model prediction algorithm's error is large. Compared with the PCRD algorithm, the proposed algorithm has the same image quality, but it saves a lot of encode passes. So it can reduce the intermediate data storage and save a lot of coding time, and it is most conducive to hardware implementation.

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