A Novel method to compress still Images using Golomb Code (GC) in JPEG2000

K.Somasundaram1[†] and P. Sumitra2[††],

[†], Department of Computer Science, Gandhigram Rural Institute, Tamil Nadu, India
[††], Department of Computer Science, Mother Teresa Women's University, Tamil Nadu, India

Summary
JPEG2000 is a widely used standard image compression method. It makes use of EBCOT to compress the co-efficients of the Discrete Wavelet co-efficients. The JPEG2000's algorithm is based on Discrete Wavelet Transform(DWT) and the Embedded Block Coding with Optimal Truncation (EBCOT). Golomb codes, a code in which no codeword is also a prefix of some other codeword. We propose that the EBCOT can be replaced by Golomb code which gives better result.

Key words:
EBCOT(EB),Golomb Code(GC), JPEG2000, Discrete Wavelet Transform(DWT).

1. Introduction

Image compression helps to reduce the cost of storing, retrieving and transferring across a network. Block Truncation Coding (BTC), Vector Quantization (VQ), Discrete Cosine Transform (DCT) and Discrete Wavelet Transform coding (DWT) [1] are some of the widely used image compression methods. The most commonly used method is JPEG2000 [2] which make use of DWT.

Embedded Block Coding Truncation (EBCOT) algorithm uses a wavelet transform to generate the subband samples which are to be quantized and coded[3]. JPEG2000 is largely derived from EBCOT and is based on the DWT, scalar quantization, context modeling, arithmetic coding and post compression rate allocation. [4].

David Taubman [5] presented a new image compression algorithm based on independent embedded block coding with optimized truncation of the embedded bit streams. The algorithm exhibits state of the art compression performance while producing a bit stream with a rich feature set, including resolution and signal to noise ratio(SNR) scalability together with a random access property. They achieved the bpp values in the range of 0.0625 to 1.0.

Rong etal [6] presented a new bit plane entropy coder which gave a 0.75% better lossless performance than JPEG2000. Rong etal [7] presented a new entropy coder, Context-Based Bit Plane Golomb Coder (CB-BPGC) for scalable image coding, which gave better coding performance than JPEG2000. Teerapat and Jeerakit [8] presented a method based on EBCOT algorithm for JPEG2000. Their algorithm outperforms JPEG2000 in encoding time while the PSNR values of the reconstructed image has been maintained at almost the same level.

Anshuman and Krishnendu [9] presented a method based on Golomb code which shows that Golomb coding of precomputed test sets leads to significant savings in peak and average power. In this paper we present a novel method of using Golomb Coding (GC) in the place of EBCOT in JPEG2000.Experimental results on standard images show that Golomb coding gives better PSNR than EBCOT.

In Section 2 we briefly outline the architecture of the JPEG2000. Existing JPEG2000 with EBCOT are described in Section 3. The proposed Golomb code, a new novel method and the Golomb code algorithm with example are proposed in Section 4. The results and discussion are given in Section 5 and the conclusion in Section 6.

2. Architecture of the JPEG2000

The block diagram of the JPEG2000 encoder is illustrated in Fig. 1. A discrete wavelet transform (DWT) is first applied on the source image data. The transform coefficients are then quantised and entropy coded, before forming the output codestream (bitstream).

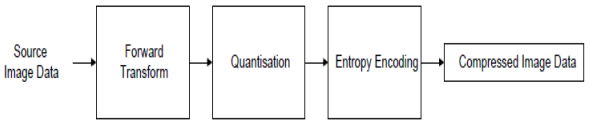

Fig. 1 Block diagram of the JPEG2000 encoder

The block diagram of the JPEG2000 decoder is illustrated in Fig. 2. The codestream is first entropy decoded, dequantised and inverse discrete transformed, providing the reconstructed image data.

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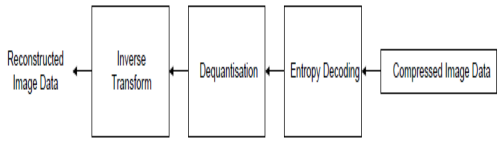

Fig. 2 Block diagram of the JPEG2000 encoder

Fig. 1 normally works on image tiles. The term 'tiling' refers to the partition of the original (source) image into rectangular non-overlapping blocks (tiles), which are compressed independently. All samples of the image tile component are DC level shifted by subtracting the same quantity from each sample Fig. 3.

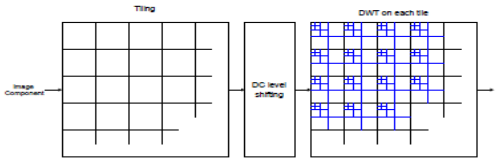

Fig. 3 DC Level Shifting

3. Existing JPEG2000 with EBCOT

We are replacing entropy coding with EBCOT. The compression engine of JPEG2000 with EBCOT is shown in Fig. 4

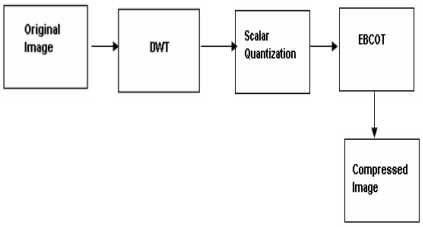

Fig. 4 Compression engine of JPEG2000 with EBCOT

The DWT is first applied on the given source image. These decomposition levels contain a number of subbands that describe the horizontal and vertical spatial frequency characteristics of the original tile component planes. The DWT coefficients are further quantized using scalar quantization. Quantisation is the process by which the transform coefficients are reduced in precision. Each subband of the wavelet decomposition is divided up into rectangular blocks, called *code-blocks*, which are coded independently using arithmetic coding. This approach, called EBCOT. Such a partitioning reduces memory requirements in both hardware and software implementations and provides a certain degree of spatial random access to the bitstream. The block size is identical for all subbands, so that blocks in lower resolution subbands span a larger region in the original image. The EBCOT algorithm is employed to compress the quantized DWT coefficients.

We carried out experiments by applying EBCOT method, with standard images of size 512 x 512 pixels "Lena", "Barbara" and "Baboon" and computed the PSNR values. We set the bit rates from 0.01 to 0.75 bpp for bandplane 0, 15, 30. But the results showed less performance.

4. The Proposed Method

The proposed method will be detailed as follows. 4.1) The Proposed Golomb Code Method 4.2) Golomb Code Algorithm

4.1 The Proposed Golomb Code Method

We now present our novel method to compress the image. Golomb coding is a lossless data compression method using a family of data compression codes invented by Golomb. .Alphabets following a geometric distribution will have a Golomb code as an optimal prefix code, making Golomb coding highly suitable for situations in which the occurrence of small values in the input stream is significantly more likely than large values [10].

Golomb coding uses a tunable parameter M to divide an input value into two parts: q, the result of a division by M, and r, the remainder. The quotient is sent in unary coding, followed by the remainder in truncated binary encoding. When $M = 1$ Golomb coding is equivalent to unary coding as shown given Fig. 5.

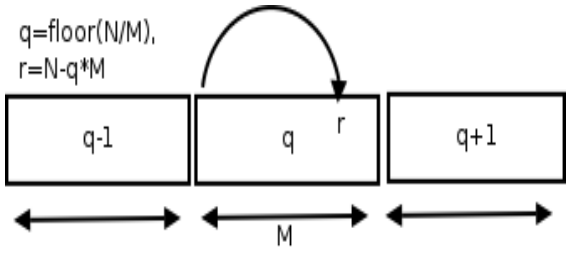

Fig. 5 Golomb Code Representation

In this paper we present a novel method using Golomb Code (GC) in the place of EBCOT. Fig. 6 shows the proposed JPEG2000 compression engine with GC.

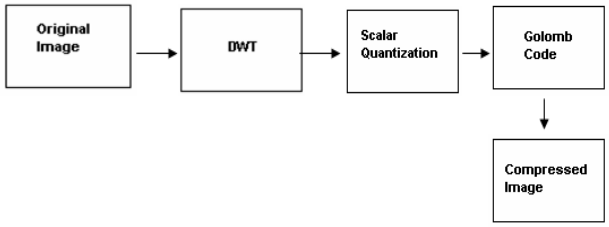

Fig.6 Compression engine of JPEG2000 with Golomb code

The DWT is first applied on the given source image. The DWT is first applied on the given source image. It decompose into number of subbands. The DWT coefficients are further quantized using scalar quantization. The Golomb code algorithm is employed to compress the quantized DWT coefficients.

4.2 Golomb Code Algorithm

The integers in a file to be compressed are performed using the following steps.

Step 1: Place the value M to an integer value.

Step 2: For the value N, the number to be encoded, Calculate the quotient and remainder by using the formulae given

quotient = q = int[N/M]

remainder = $r = N$ modulo M

Step 3: Generate Codeword

Step 4: Write a q-length string of 1 bits

Step 5: Write a 0 bit

Step 6: Remainder Code (in truncated binary encoding)

Step 7: If M is power of 2, code remainder as binary format.

Step 8: If M is not a power of 2, set

$$b = \lceil \log_2(M) \rceil \quad (1)$$

Step 9: If $r < 2b - M$ code r as plain binary using b-1 bits.

Step10: If

$$r \geq 2^b - M \quad (2)$$

code the number $r + 2b - M$ in plain binary representation using b bits.

Example

When n = 5 d = 3

q = (5 – 1) / 3

= 4/3

= 1

r = 5 - 1 x 3 - 1

= 5 - 3 - 1

= 5 – 4

= 1

First part is the value q+1

When q + 1 we get q = 1+1 =2, coded in binary

Second part is binary value of r. Partitioning we get 10 | 10 for n =5

When d = 3, it produces three possible remainders 0, 1, 2 we get 0, 10 and 11, respectively and are given in the Table 1 and Table 2 shows the GC for remainders d = 3 and d = 4.

Table 1: Codes for remainders

Remainders(r)	GC	
	d =3	d=4
0	0	0
1	10	1
2	11	10
3	-	11

Table 2: GC for d = 3 and d = 4

n	d= 3	d=4
1	0 | 0	0|0
2	0|10	0|1
3	0|11	0|10
4	10|0	0|11
5	10|10	10|00
6	10|11	10|01
7	110	10|10
8	110|10	10|11
9	110|11	110|00
10	1110|0	110|01
11	1110|10	110|10
12	1110|11	110|11
13	11110|0	1110|00
14	11110|10	1110|01
15	11110|11	1110|10

5. Results and Discussion

We carried out experiments by applying EBCOT method, with standard images of size 512 x 512 pixels

"Lena", "Barbara" and "Baboon" and computed the PSNR values.

Table 3: PSNR values for EBCOT, Golomb code, TJ for different bpp and bandplanes 0, 15, 30 for Lena image

bpp	Band Plane(0)			Band Plane(15)			Band Plane(30)		
	EB	TJ [8]	GC	EB	TJ [8]	GC	EB	TJ [8]	GC
0.01	28.14	28.14	29.09	28.30	28.30	28.53	28.32	28.32	28.92
0.1	32.79	32.79	33.27	32.89	32.89	33.78	32.92	32.92	33.68
0.2	35.68	35.68	36.13	35.88	35.88	36.83	36.10	36.10	36.92
0.3	38.73	38.73	39.17	39.48	39.48	40.09	39.67	39.67	40.46
0.4	42.80	42.80	43.72	43.12	43.12	43.85	43.22	43.22	43.39
0.5	46.20	46.20	47.13	47.25	47.25	48.16	47.25	47.25	47.66
0.6	52.06	52.06	52.95	52.06	52.06	52.11	52.06	52.06	52.41
0.7	67.71	67.71	68.52	67.71	67.71	67.71	67.71	67.71	67.84
0.75	67.71	67.71	67.91	67.71	67.71	67.90	67.71	67.71	68.31

We set the bit rates from 0.01 to 0.75 bpp for band planes 0, 15 and 30 and the results for Lena image are given in Table 3, Baboon in Table 4 and Barbara in Table 5. For comparison the results obtained for JPEG2000 with EBCOT and that of Teerapat and Jeerakit (TJ)[8] are also given.

We note that the value of PSNR obtained by the proposed method is better than EBCOT and TJ method for all bit rates 0.01 to 0.75 bpp. As bpp increases the performance of all the three methods approach the same level in terms of PSNR.

Table 4: PSNR values for EBCOT, Golomb code, TJ for different bpp and bandplanes 0, 15, 30 for Baboon image

bpp	Band Plane(0)			Band Plane(15)			Band Plane(30)		
	EB	TJ [8]	GC	EB	TJ [8]	GC	EB	TJ [8]	GC
0.01	20.90	20.90	21.83	21.03	21.03	22.00	21.04	21.04	22.03
0.1	27.51	27.51	28.46	27.92	27.92	28.50	27.97	27.97	28.92
0.2	31.20	31.20	32.13	31.46	31.46	32.42	31.66	31.66	32.65
0.3	34.47	34.47	35.46	35.12	35.12	36.07	35.72	35.72	36.71
0.4	38.02	38.02	38.97	39.36	39.36	40.33	39.63	39.63	40.62
0.5	42.08	42.08	43.06	43.01	43.01	43.91	43.27	43.27	44.26
0.6	46.20	46.20	47.13	47.3	47.30	48.25	47.3	47.30	48.29
0.7	52.07	52.07	53.02	52.07	52.07	53.06	52.07	52.07	53.02
0.75	63.87	63.87	64.85	63.87	63.87	64.86	63.87	63.87	64.21

Table 5: PSNR values for EBCOT, Golomb code, TJ for different bpp and bandplanes 0, 15, 30 for Barbara image

bpp	Band Plane(0)			Band Plane(15)			Band Plane(30)		
	EB	TJ [8]	GC	EB	TJ [8]	GC	EB	TJ [8]	GC
0.01	19.48	19.48	20.40	19.52	19.52	22.00	19.53	19.53	20.46
0.1	23.18	23.18	24.29	23.44	23.44	28.50	23.45	23.45	24.44
0.2	26.26	26.26	27.21	26.66	26.66	32.42	26.86	26.86	27.79
0.3	29.75	29.75	30.71	29.86	29.86	36.07	30.69	30.69	30.73
0.4	32.96	32.96	33.95	34.61	34.61	40.33	35.52	35.52	36.47
0.5	37.51	37.51	38.44	38.18	38.18	43.91	40.06	40.06	41.05
0.6	41.45	41.45	42.44	42.48	42.48	48.25	43.85	43.85	44.81
0.7	46.37	46.37	47.24	47.43	47.43	53.06	47.85	47.85	48.80
0.75	48.89	48.89	49.88	50.39	50.39	64.86	50.39	50.39	51.38

For visual comparison the reconstructed image of Lena for Golomb code are shown in Fig. 7.

(a) **(b)** **(c)**

Fig.7 Reconstructed Image of Lena for GC band plane = 0
a) bpp=0.01 PSNR = 29.01
b) bpp = 0.40 PSNR = 43.72
c) bpp=0.75. PSNR = 67.91

6. Conclusion

We have designed a modified JPEG2000 by replacing EBCOT by Golomb code method. Experimental results of our scheme on standard images show that the proposed methods perform better than JPEG2000 with EBCOT and that of TJ[8]. The proposed method performs much better at lower bpp than that of JPEG2000 and TJ method.

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K. Somasundaram received his Ph.D Degree from Indian Institute of Science, Bangalore, India in 1984, the M.Sc Degree from Madras University, Tamilnadu, India in 1976, and the PGDCM from Madurai Kamaraj University, Tamilnadu, India in 1989. He is a Professor and Head of the Department of Computer Science and Applications of the Gandhigram Rural University, Gandhigram, Tamilnadu, India. His areas of research include Multimedia, Data Compression, Multimedia for Teaching, PC-Based instrumentation and Computational Plasma Physics. He is a member of ISTE India, ACM USA, and IEE Computer Society, USA.

P. Sumitra received her M.Phil Degree in Computer Science from Mother Teresa Women's University, Kodaikannal, Tamil Nadu, India in the year 2003 and received her M.Sc Degree in Computer Science from Madurai Kamaraj University, Madurai, TamilNadu, India in the year 1998. She is currently doing her Ph.D.