Quantization Skipping Method for H. 264/AVC Video Coding

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Abstract – This paper presents a quantization skipping method for H. 264/AVC video coding standard. In order to reduce the computational-cost of quantization process coming from integer discrete cosine transform of H. 264/AVC, a quantization skipping condition is derived by the analysis of integer transform and quantization procedures. The experimental results show that the proposed algorithm has the capability to reduce the computational cost about 10% ~ 25%.

Key words – ***H.*** 264/***AVC***; ***quantization skipping***; ***integer transform***; ***computational-cost***

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1 Introduction

H. 264 video coding standard has been jointly developed to obtain better coding performance than the other video coding standards by ITU-T and ISO[1-3]. It has been reported that the major coding gain comes from spatial intra prediction, 4 × 4 block-based integer transform, variable block size motion estimation and so on Ref. [2].

As the other video coding standards, transform and quantization are used as the key steps to reduce the spatial information representing a source image in H. 264/AVC video coding standard, Even though H. 264/AVC outperforms the other existing video coding standards, it requires very expensive computational cost.

Integer Discrete Cosine Transform (DCT) has been employed in order to solve well-known Inverse Discrete Cosine Transform (IDCT) mismatch problem, but it increases the computational cost of quantization process. Many approaches have been exploited to reduce the complexity of transform and quantization of the previous video coding standards. Early detection methods for all-zero DCT coefficients were reported in the literature [4-6]. Also, in Ref. [7], a more precise sufficient condition was defined by modifying the calculation order of the Sum of Absolute Difference (SAD) obtained form motion estimation of H. 264/AVC video coding standard. Also, similar technique to incorporate knowledge of the DCT and quantization into the encoder has been reported[7-8]. The above approaches are useful to reduce the complexity for MPEG2, MPEG4-Part 2. Therefore, when the different coding scheme such as H. 264/AVC is used, the different criterion or condition should be used.

In this paper, we present the quantization skipping condition by analyzing the integer DCT and quantization processes for H. 264/AVC.

This paper is organized as follows. In section 2, a quantization skipping algorithm for H. 264/AVC is described. The proposed condition is induced by rigorous analysis of transform and quantization of H. 264/AVC video coding. Finally, the experimental results and conclusion are described in section 3 and 4.

2 Quantization skipping condition for H. 264/AVC

H. 264/AVC video coding standard is different to the other video coding standards in that it uses 4 × 4 integer transform, spatial intra prediction, variable block-size motion estimation/compensation, and so on. Therefore, transform coefficients or quantization coefficients have different distribution to the other video coding standards.

In H. 264/AVC, the residual frame between an original frame and the corresponding intra/inter predicted frame is obtained and the integer-transformed and quantized in H. 264/AVC. In general video coding standards, a linear quantization has been used to assign a transformed signal to a pre-designed reconstructed value. When a linear quantization is used, the maximum value or quantization coefficients of a block should satisfy the following condition[4-5]

$$\max_{ij} |Z_{ij}| < 2 \times Q\text{step}. \quad (1)$$

Where Z_{ij} and Qstep, represent the (i, j)-th quantized coefficient and quantization step size, respectively. Also max denotes the maximum operator. The quantization process of H. 264/AVC is complicated by the requirements to (a) avoid division and/or floating point arithmetic and (b) incorporate the post- and pre-scaling[3]. The (i, j)-th quantized coefficient is determined as

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$$Z_{ij} = \text{round}(W_{ij}\frac{PF}{Q\text{step}}), \tag{2}$$

where W_{ij} and PF denote the (i,j)- th integer transformed coefficient and the corresponding post scaling factor having a value within block as shown in Tab.2. In addition, represents the round-off operator. In order to simplify the process, the factor (PF/Qstep) is implemented as a multiplication by a factor mf and a right-shift operation. Then, the Eq.(2) can be written as

$$Z_{ij} = \text{round}(W_{ij}\frac{MF}{2^{q\text{bits}}}), \tag{3}$$

where MF represents a multiplication factor to avoid multiplication and division operations as shown in Tab.3[9]. Also, in the Eq.(3), floor (x) is an operatr to represent the greatest integer less or equal to x .

Tab.1 Quantization step size of H.264/AVC video coding standard

Qp	0	1	2	3	4	5	6
Q step	0.625	0.687 5	0.182 5	0.875	1	1.125	1.25
Qp	7	8	9	10	11	12	…
Q step	1.37	1.625	1.75	2	2.25	2.5	…
Qp	…	18	…	24	…	30	…
Q step	…	5	…	10	…	20	…
Qp	36	…	42	…	48	…	51
Q step	40	…	80	…	160	…	224

Tab.2 Post scaling factor PF: $a = \frac{1}{2}$, $b = \sqrt{\frac{1}{2}}\cos(\frac{\pi}{8})$, $c = \sqrt{\frac{1}{2}}\cos(\frac{3\pi}{8})$

Position	Post scaling factor
(0,0),(2,0),(0,2) or (2,2)	a^2
(1,1),(1,3),(3,1) or (3,3)	$b^2/4$
Other	$ab/2$

Tab.3 Multiplication factor, MF

Qp	Position (0,0),(2,0),(0,2) or (2,2)	Position (1,1),(1,3),(3,1) or (3,3)	Other position
0	13 107	5 243	8 066
1	11 916	4 660	7 490
2	10 082	4 194	6 554
3	9 362	3 647	5 825
4	8 192	3 355	5 243
5	7 282	2 893	3 449

From equations (1) and (3), the following condition can be derived to skip quantization process for a 4×4 block

$$\max_{ij} |W_{ij}| < 2 \times |\frac{PF}{MF} \times 2^{q\text{bits}}| \times Q\text{step}. \tag{4}$$

H.264/AVC uses the quantization index to control the bit rate as the quantization parameter. Therefore, it is necessary to define the relation between the quantization index and the quantization step size. In our previous work [10], the relation was derived from the quantization process. Using the quantization step size for given QP , the Eq.(4) is used as a condition for skipping the quantization process of H.264/AVC by early detection of all zero integer transform coefficients before the quantization.

3 Experimental results

A number of experiments have been conducted with various sequences and different resolutions at a number of quantization indices. Among them, QCIF "Forman", "Claire" and "Hall monitor" sequences are described in the experimental results. The proposed algorithm was tested with JM12.1 (Joint Model 12.1) reference code of H.264/AVC video coding standard. For evaluating the performance of the algorithm, Peak Signal to Noise Ratio (PSNR) was used. For $M \times N$ size 8 bits image, it is defined as

$$\text{PSNR} = 10\log\frac{MN \times 255^2}{\| f - \hat{f} \|^2}, \tag{5}$$

where $\|\cdot\|$ represents the Euclidean norm, and f and $\hat{f}$ denote an original image and the reconstructed image, respectively.

Tables 4~6 show the performance comparisons as a function of Qp , when encoding frame rate is 10 frames 3 Per second, the results show that the proposed algorithm has the capability to consistently reduce the computational cost without the degradation of coding performance. As QP is higher (bit rate is lower), the reduction of computation-cost is higher since relatively many skip blocks are required at lower bit rate.

Tab.4 PSNR by QP QCIF foreman sequence, bitrate and operation time gain comparison table

Qp	Method	PSNRY (dB)	PSNRU (dB)	PSNRV (dB)	Bitrate (kbps)	OP time (sec)
16	H.264	45.01	46.19	47.13	340.11	0.657
	Prop.	45.01	46.19	47.13	340.11	0.594
24	H.264	38.61	41.93	42.93	127.16	0.627
	Prop.	38.61	41.93	42.93	127.16	0.552
32	H.264	33.06	39.08	39.48	46.09	0.547
	Porp.	33.06	39.08	39.48	46.09	0.422
40	H.264	28.04	36.90	36.89	18.30	0.521
	Prop.	28.04	36.90	36.89	18.30	0.401

Tab.5 PSNR by QP QCIF hall monitor sequence, bitrate and operation time gain comparison table

Qp	Method	PSNRY (dB)	PSNRU (dB)	PSNRV (dB)	Bitrate (kbps)	OP time (sec)
16	H.264	45.10	44.84	45.33	253.74	0.608
	Prop.	45.10	44.84	45.33	253.74	0.558
24	H.264	39.78	40.90	42.71	51.89	0.584
	Prop.	39.78	40.90	42.71	51.89	0.528
32	H.264	34.23	38.1	40.30	19.00	0.569
	Porp.	34.23	38.1	40.30	19.00	0.486
40	H.264	28.58	36.29	39.04	7.25	0.541
	Prop.	28.58	36.29	39.04	7.25	0.448

Tab. 6 PSNR by *QP* QCIF claire sequence, bitrate and operation time gain comparison table

Qp	Method	PSNRY (dB)	PSNRU (dB)	PSNRV (dB)	Bitrate (kbps)	OP time (sec)
16	H. 264	47.75	47.51	48.63	102.10	0.558
	Prop.	47.75	47.51	48.63	102.10	0.598
24	H. 264	42.56	42.15	44.25	35.21	0.547
	Prop.	42.56	42.15	44.25	35.21	0.454
32	H. 264	36.89	37.89	40.13	11.59	0.533
	Porp.	36.89	37.89	40.13	11.59	0.405
40	H. 264	31.31	35.12	37.65	4.33	0.516
	Prop.	31.31	35.12	37.65	4.33	0.392

Tab. 7 Reliability table of quantization skip process by *QP* of QCIF foreman sequence

Qp	Luminance			Chrominance		
	Fault (EA)	Miss (EA)	Success (EA)	Fault (EA)	Miss (EA)	Success (EA)
16	0	39 854	163 602	0	16.140	7.787
24	0	5 007	218 177	0	12.013	15 702
32	0	513	259 375	0	4 098	18 190
40	0	71	291 353	0	830	18 970

Tab. 8 Reliability table of quantization skip process by *QP* of QCIF hall monitor sequence

Qp	Luminance			Chrominance		
	Fault (EA)	Miss (EA)	Success (EA)	Fault (EA)	Miss (EA)	Success (EA)
16	0	27 792	243 344	0	18 165	1 635
24	0	972	292 692	0	4 904	14 896
32	0	37	297 771	0	866	18 934
40	0	8	305 560	0	177	19 623

Tab. 9 Reliability table of quantization skip process by *QP* of QCIF claire sequence

Qp	Luminance			Chrominance		
	Fault (EA)	Miss (EA)	Success (EA)	Fault (EA)	Miss (EA)	Success (EA)
16	0	6 087	263 193	0	6 999	12 801
24	0	458	281 558	0	1 073	18 727
32	0	42	300 454	0	355	19 445
40	0	1	310 495	0	128	19 672

The reliability of the proposed algorithm is shown in Tab. 7~9. In the tables, "Fault" means the block that is incorrectly judged as a skip block even though it is not skip block. "Missing" represents the block that is not detected as a skip block. On the other hand, "Success" denotes the case to be correctly judged as a skip block. From the results, it is verified that with the proposed algorithm the quantization skip blocks more than 95(%) are correctly detected, and that the computational cost is reduced about 20(%).

Novelty of the proposed algorithm is that the quantization skip block is early detected without the loss of coding efficiency, resulting in reduction of computational-cost.

4 Conclusion

In this paper, we propose a quantization skipping condition for H.264/AVC video coding standard by early detection of all zero integer transformed coefficients. The skipping condition of computational-cost is derived from the integer DCT and the quantization processes. From the experimental results, it is observed that the proposed algorithm consistently results in computational-cost reduction about 10%~25% against H.264/AVC reference software without the loss of coding efficiency.

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