Determination Method of Quantization Skipping Condition for H.264/AVC Video Coding

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***Abstract*- In this paper, we present an efficient method to determine the quantization skipping condition for H.264/AVC video coding. In order to reduce the operation time of quantization process that is coming from integer discrete cosine transform, a quantization skipping condition is derived by the analysis of integer transform and quantization processes. The experimental results show that the proposed algorithm has the capability to reduce the computational complexity about 10-25(%).**

Keywords: H.264/AVC, quantization, transform, skipping condition.

I. INTRODUCTION

The video coding standards are established for providing video services in many applications of wire, wireless communication or multimedia services. Among the various video coding standards, especially H.264/AVC video coding standard can be adopted to provide high compressions and used in many applications.

JVT(Joint Video Team) established by ITU-T and ISO/IEC has jointly developed H.264/AVC video coding standard can be characterized by block-based integer transform, variable block-size motion estimation and compensation, and spatial intra prediction and so on [1]-[3]. Due to the different coding strategies, the transform and quantization process of H.264/AVC video coding standard are different to previous standard. Therefore, any algorithms to obtain better coding efficiency should be different to other standards.

Many approaches have been exploited to reduce the complexity of transform and quantization in previous video encoder. Ref. [4] proposed an early detection method for all-zero block. They defined a condition for checking all DCT(Discrete Cosine Transform) coefficients to zero. In Ref. [5], they theoretically derived more accurate condition than Ref. [4]. Also, Ref. [6] proposed an efficient method for early detection of all zero DCT coefficients. Ref. [7] is defined a more precise sufficient condition by modifying the calculation order of the SAD(Sum of Absolute Difference) obtained from 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 [8]-[10].

These approaches were developed for MPEG2, MPEG4-Part2. 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 proposed that a determination method of quantization skipping condition is derived to reduce the operation time using integer discrete cosine transform and quantization of H.264/AVC video coding standard.
This paper is organized as follows. Section II describes the background of the transform and quantization process in H.264/AVC video coding standard. In Section III, we present the proposed algorithm for quantization skipping condition. The proposed threshold is induced by rigorous analysis of transform and quantization for H.264/AVC video coding. Finally, the experimental results and conclusion are described in Section IV, and V.

II. TRANSFORM AND QUANTIZATION IN H.264/AVC VIDEO CODING STANDARD

H.264/AVC Video coding standard is based on 4×4 integer transform, intra prediction, and block-based motion estimation/compensation and has a different signal distribution from previous video coding standard. Therefore, the skip algorithm for quantization should be differently applied. In general, SAD(Sum of Absolute Difference) obtained from motion estimation is used to find the best matching block and defined as,

$$\begin{aligned} SAD &= \sum_{x=0}^{N-1}\sum_{y=0}^{N-1}\left|e(x,y)\right| \\ &= \sum_{x=0}^{N-1}\sum_{y=0}^{N-1}\left|f_t(x,y)-f_{t-1}\left(x+v_x,y+v_y\right)\right| \end{aligned} \tag{1}$$

where $f_t(x,y)$ and $f_{t-1}\left(x+v_x,y+v_y\right)$ denote the $N\times N$ size current frame and previous frame, and $\left(v_x,v_y\right)$ means the motion vector from motion estimation. Also an error residual value, $e(x,y)$, denotes the difference value between the current and the previous frame.

For $N\times N$ size block, its integer transform can be defined as

$$E_T(u,v)=\sum\sum e(x,y)\left[k(u)\cos\frac{2x+1}{2N}u\pi\right]\left[k(v)\cos\frac{2y+1}{2N}v\pi\right]$$

$$k(u),k(v)=\begin{cases}1/\sqrt{2}, & u,v=0\\ 1, & u,v\neq 0\end{cases} \tag{2}$$

where the $\lceil\ \rceil$ in Eq. (2) denotes the rounding-off operation.

H.264/AVC video coding standard uses 4×4 n integer transform for solving a mismatch problem and realizing it effectively. The 4×4 block integer transform represents to matrix form.

$$\begin{bmatrix} 1 & 1 & 1 & 1 \\ 2 & 1 & -1 & -2 \\ 1 & -1 & -1 & 1 \\ 1 & -2 & 2 & -1 \end{bmatrix} \begin{bmatrix} e_{00} & e_{01} & e_{02} & e_{03} \\ e_{10} & e_{11} & e_{12} & e_{13} \\ e_{20} & e_{21} & e_{22} & e_{23} \\ e_{30} & e_{31} & e_{32} & e_{33} \end{bmatrix} \begin{bmatrix} 1 & 2 & 1 & 1 \\ 1 & 1 & -1 & -2 \\ 1 & -1 & -1 & 2 \\ 1 & -2 & 1 & -1 \end{bmatrix} \quad (3)$$

where the e_{ij} in Eq. (3) denotes the (i,j)-th pixel on error residual block. It can be computed by a shift- and an addition operation without multiplication. Also, given a transform coefficient, $E_T(u,v)$, the quantized coefficient is defined as

$$E_q(u,v) = \frac{E_T(u,v)\cdot A(Q_M,u,v) + f}{2^{15+Qp/6}} \quad (4)$$

$$\text{where, } Q_M = Q_P \bmod 6.$$

In Eq. (4), f and $A(Q_M,u,v)$ denote the constant range from 0 to $2^{16+Qp/6}$ and scaling factor for quantization parameter, where a scaling factor is defined as

$$A(Q_M,u,v) = M(Q_M,r) = \begin{bmatrix} 13107 & 5243 & 8066 \\ 11916 & 4660 & 7490 \\ 10082 & 4194 & 6554 \\ 9362 & 3647 & 5825 \\ 8192 & 3355 & 5243 \\ 7282 & 2893 & 4559 \end{bmatrix}$$

$$\begin{array}{ll} r=0, & (u,v)=\{(0,0),(0,2),(2,0),(2,2)\} \\ r=1, & (u,v)=\{(1,1),(1,3),(3,1),(3,3)\} \quad , \\ r=2, & \quad otherwise \end{array} \quad (5)$$

Also, the parameter Q_p denotes a quantization index that is a value between 0 and 51. Using the relationship between quantization index and quantization step size that is described in H.264/AVC, quantization step size for each quantization index can be represented as Table I.

TABLE I
THE QUANTIZATION STEP SIZE OF H.264/AVC VIDEO CODING STANDARD

Qp	0	1	2	3	4	5	6
Qstep	0.625	0.6875	0.1825	0.875	1	1.125	1.25
Qp	7	8	9	10	11	12	…
Qstep	1.37	1.625	1.75	2	2.25	2.5	…
Qp	…	18	…	24	…	30	…
Qstep	…	5	…	10	…	20	…
Qp	36	…	42	…	48	…	51
Qstep	40	…	80	…	160	…	224

III. DETERMINATION METHOD OF QUANTIZATION SKIPPING CONDITION FOR H.264/AVC VIDEO CODING STANDARD

In this section, we describe a determination method of quantization skipping condition without additional computation. A general discrete cosine transform has a linear quantizer as MPEG-4. Then, the maximum value of quantized transform coefficient should satisfy the following condition such as [4], [5]

$$\max_{ij}\left|Z_{ij}\right| < 2\times Qstep \quad (6)$$

where Z_{ij} , $Qstep$, and max denote the (i,j) -th quantized coefficients, quantization step size, and the maximum operation, respectively.

On the other hands, H.264/AVC video coding standard uses a nonlinear quantization such as

$$Z_{ij} = round\left(W_{ij}\frac{PF}{Qstep}\right) \quad (7)$$

In Eq. (7), W_{ij} denotes the core transform coefficient of H.264/AVC video coding standard and PF is a post scaling factor having a value of pixel position within 4×4 blocks as shown Table II [3].

TABLE II
THE POST SCALING FACTOR, PF

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	$ab/2$

In order to simplify the process, the factor $(PF/Qstep)$ is implemented in the reference model software as a multiplication by a factor MF and a right-shift, avoiding any division operations. It is

$$Z_{ij} = round\left(W_{ij}\frac{MF}{2^{qbits}}\right) \quad (8)$$

where the multiplication factor, MF denotes the factor for avoiding multiplication and division operation and $qbits$ is defined as $Qp\%6$. Also $round(\cdot)$ represents the round-off operator.

From Eq. (7) and (8), we can derive a condition to skip the quantization for fast video coding,

$$\max_{ij}\left|W_{ij}\right| < 2\times\left|\frac{PF}{MF}\times 2^{qbits}\right|\times Qstep. \quad (9)$$

where $Qstep$ represents the quantization step size shown in Table I. Eq. (9) is used as a condition for skipping quantization in our proposed algorithm.

TABLE III
THE MULTIPLICATION FACTOR, MF

Qp%6	Position (0,0), (2,0), (0,2), or (2,2)	Position (1,1), (1,3), (3,1), or (3,3)	Other Position
0	13107	5243	8066
1	11916	4660	7490
2	10082	4194	6554
3	9362	3647	5825
4	8192	3355	5243
5	7282	2893	3449

IV. EXPERIMENTAL RESULTS

A number of experiments have been conducted with various sequences and different resolutions at a number of quantization indices. Among of them, QCIF "Foreman" sequence, "Claire" sequence, and "Hall monitor" sequence were used. The proposed algorithm was tested with JM9.0 (Joint Model 9.0) reference code of H.264/AVC video coding standard. For evaluating the performance of the algorithm, PSNR (Peak Signal to Noise Ratio) was utilized. For $M \times N$ size 8bits image, it is defined as

$$PSNR = 10\log\frac{MN \times 255^2}{\left\| f - \hat{f} \right\|^2}. \qquad (10)$$

where $\|\cdot\|$ is the Euclidean norm, and f and $\hat{f}$ represent the original image and the reconstructed image, respectively.

In Table IV, V and VI, we present the PSNR, bitrates and encoding time comparison as a function of quantization index for QCIF "Foreman", "Claire", and "Hall monitor" sequences. There is no loss of the PSNR and bitrates but the operation time is only decreased when skipping quantization. From the results, it is verified that the coding performance keeps without the degradation of coding performance.

Table VII, VIII, and IX represent the reliability table of quantization skip process by QP. From these tables, the 'Miss' means the quantized block is skipped when the block is not satisfied by its condition. The 'Fault' means the quantized block is not skipped when the block's condition is satisfied. And the 'Success' means that it became skip by the proposed method precisely.

From as a result, it is verified that the proposed method reduced the operation time while maintaining bitrates.

From the experiments, it is verified that the 'Fault' block doesn't make any more and the 'Miss' block decreases by QP. We can show that the proposed algorithm has the capability to reduce the operation time of quantization about 10~25(%) preserving same bitrates and PSNR.

V. CONCLUSION

In this paper, we propose a determination method of quantization skipping condition for H.264/AVC video coding standard. The skipping condition without additional computations is introduced and the characteristics of H.264/AVC are applied into the algorithm. The parameters are defined to control the robust condition. From the experimental results, it is observed that the proposed algorithm consistently results in operation time saving about 10~25(%) against the original JM reference code. Also, it is verified that the proposed algorithm effectively reduces the computational complexity, leading to satisfactory results.

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TABLE IV
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
	Prop.	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

TABLE V
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	44.26	35.21	0.547
	Prop.	42.56	42.15	44.26	35.21	0.454
32	H.264	36.89	37.89	40.13	11.59	0.533
	Prop.	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

TABLE VI
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
	Prop.	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

TABLE VII
RELIABILITY TABLE OF QUANTIZATION SKIP PROCESS BY QP OF QCIF FOREMAN SEQUENCE

Qp	Meth.	Luminance			Chrominance		
		Fault [EA]	Miss [EA]	Success [EA]	Fault [EA]	Miss [EA]	Success [EA]
16	H.264	-	-	-	-	-	-
	Prop.	0	39,854	163,602	0	16,140	7,787
24	H.264	-	-	-	-	-	-
	Prop.	0	5,007	218,177	0	12.013	15,702
32	H.264	-	-	-	-	-	-
	Prop.	0	513	259,375	0	4,098	18,190
40	H.264	-	-	-	-	-	-
	Prop.	0	71	291,353	0	830	18,970

TABLE VIII
RELIABILITY TABLE OF QUANTIZATION SKIP PROCESS BY QP OF QCIF CLAIRE SEQUENCE

Qp	Meth.	Luminance			Chrominance		
		Fault [EA]	Miss [EA]	Success [EA]	Fault [EA]	Miss [EA]	Success [EA]
16	H.264	-	-	-	-	-	-
	Prop.	0	6,087	263,193	0	6,999	12,801
24	H.264	-	-	-	-	-	-
	Prop.	0	458	281,558	0	1,073	18,727
32	H.264	-	-	-	-	-	-
	Prop.	0	42	300,454	0	355	19,445
40	H.264	-	-	-	-	-	-
	Prop.	0	1	310,495	0	128	19,672

TABLE IX
RELIABILITY TABLE OF QUANTIZATION SKIP PROCESS BY QP OF QCIF HALL MONITOR SEQUENCE

Qp	Meth.	Luminance			Chrominance		
		Fault [EA]	Miss [EA]	Success [EA]	Fault [EA]	Miss [EA]	Success [EA]
16	H.264	-	-	-	-	-	-
	Prop.	0	27,792	243,344	0	18,165	1,635
24	H.264	-	-	-	-	-	-
	Prop.	0	972	292,692	0	4,904	14,896
32	H.264	-	-	-	-	-	-
	Prop.	0	37	297,771	0	866	18,934
40	H.264	-	-	-	-	-	-
	Prop.	0	8	305,560	0	177	19,623