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Intra Prediction using Weighted Average of Pixel Values According to Prediction Direction

Kibaek Kim, Dongjin Jung, Jinik Jang and Jechang Jeong

***Abstract*—**In this paper, we proposed a method to reduce quantization error. In order to reduce quantization error, low pass filtering is applied on neighboring samples of current block in H.264/AVC. However, it has a weak point that low pass filtering is performed regardless of prediction direction. Since it doesn't consider prediction direction, it may not reduce quantization error effectively. Proposed method considers prediction direction for low pass filtering and uses a threshold condition for reducing flag bit. We compare our experimental result with conventional method in H.264/AVC and we can achieve the average bit-rate reduction of 1.534% by applying the proposed method. Bit-rate reduction between 0.580% and 3.567% are shown for experimental results.

***Keywords*—**Coding efficiency, H.264/AVC, Intra prediction, Low pass filter

I. Introduction

THE Joint Video Team (JVT) of ISO/IEC MPEG and ITU-T VCEG finalized a standard, H.264 and MPEG-4 Part 10 Advanced Video Coding (AVC)[1]-[3], for video coding. Since H.264/AVC adopted advanced prediction techniques, H.264/AVC achieved both better coding efficiency and improved visual quality than the previous video coding standards: directional spatial prediction for intra coding, variable block size for motion estimation/ motion compensation (ME/MC) based on quarter-pixel accuracy, multiple reference pictures, in-loop deblocking filter, context adaptive entropy coder (CABAC, CAVLC), and so on. Intra prediction makes use of spatial correlation of local region. To be specific, intra prediction of H.264/AVC predicts pixel values directionally in spatial domain and it can be used in both intra and inter frame coding as the counterpart of temporal prediction. The directional spatial prediction is one of techniques that significantly improve the coding efficiency of the H.264/AVC intra coding. H.264/AVC has nine prediction modes for 4x4 block size, and four prediction modes for 16x16 block size. All samples of current block are predicted by reconstructed neighboring pixels. Since neighboring blocks are coded areas, it may have quantization error that influences accuracy of prediction. In H.264/AVC low pass filtering is applied on neighboring samples for reducing quantization error.

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The authors are with the Department of Electronics and Computer engineering, Hanyang University, Seoul 133-791, Korea (e-mail: k2b0002@hanyang.ac.kr; dlying@hanyang.ac.kr; jji0678@gmail.com; jjeong@ece.hanyang.ac.kr).

These days several tools were studied to improve coding efficiency for reducing quantization error in intra prediction. Call for proposal[4] containing adaptive intra smoothing (AIS) [5][6] is proposed on High-Efficiency Video Coding (HEVC) in MPEG meeting. In AIS, it is signaled per block whether low pass filtering is performed or not. However, it has the weak point that low pass filtering is performed irrespective of direction of prediction. It may not reduce quantization error efficiently. In this paper new method is proposed for reducing quantization error.The rest of this paper is consisted as follows: Section Ⅱ introduces the intra prediction and the conventional method for reducing quantization error. Section Ⅲ deals with demerit of conventional method and proposed method for reducing quantization error according to direction of prediction. The experimental results of the proposed method are provided in Section Ⅳ. Finally, conclusion is drawn in Section Ⅴ.

II. Conventional Method

A. Intra prediction

In H.264/AVC, the intra prediction is performed as block-based manner and block is predicted by reconstructed adjacent pixels. Intra 16x16, Intra 8x8 (FRExt-only[7]), and Intra 4x4 prediction have different kinds of intra prediction modes and are used to encode luminance components. Only one prediction mode is applied for the whole macroblock in Intra 16x16 prediction. Four prediction modes are supported for Intra 16x16 prediction: vertical prediction, horizontal prediction, DC prediction, and plane prediction. The efficiency of Intra 16x16 prediction is high if the signal is smooth within the macroblock.And a macroblock can be divided into sixteen 4x4 sub-blocks and each 4x4 sub-block can be predicted individually in Intra 4x4 prediction. There are nine prediction modes for the 4x4 sub-block in Intra 4x4 prediction: DC prediction mode, which predicts all samples of the current 4x4 subblock by mean of reconstructed neighboring pixels which are located in left and top of the current block, and eight directional prediction modes. Eight prediction modes are shown in Fig. 1. In FRExt, Intra 8x8 prediction has the same prediction mode like Intra 4x4 prediction.

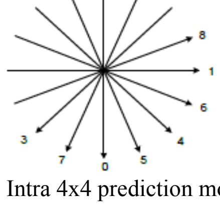


Fig. 1 Intra 4x4 prediction mode

The encoder determines the best prediction mode of the current block by a Lagrangian cost function which considers both distortion and bit rate of the current block. Rate-Distortion Optimization (RDO) [8] determines which mode is used for coding each macroblock/block by minimizing the following:

$$J = D + \lambda \cdot R \tag{1}$$

where J, D, λ, R denote respectively RD cost of selected mode, distortion, the Lagrangian multiplier and bit rate.

As shown in Fig. 2, pixels in the 4x4 block are written as lower case, whereas pixels on neighboring block are written as upper case. Pixels on neighboring block are used to predict current block according to the direction of prediction. For example, if the horizontal mode, mode 1, is selected, pixel a, e, i and m are predicted by pixels (I_0, J_0, K_0, L_0) of left block. The other modes are the same, unless the direction is different.

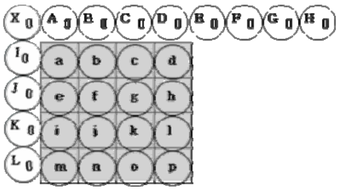
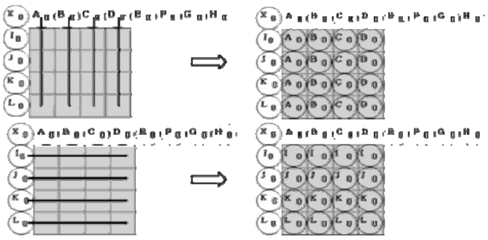


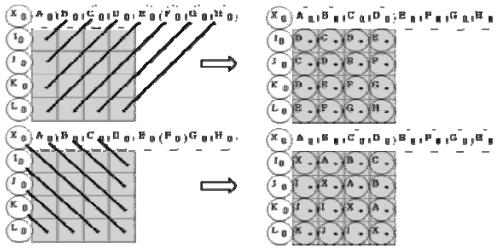
Fig. 2 Neighboring pixels in 4x4 block

B. Low pass filtering in H.264/AVC

Spatial redundancies are reduced by intra prediction. Since the current block is predicted by pixels from neighboring block which have been already reconstructed, accuracy of prediction of current block may be affected by quantization error of neighboring pixels. For reducing the quantization error, H.264/AVC adopted low pass filter with 3-tap (¼, ½, ¼) on pixels of neighboring block as shown in Fig. 3. Vertical and horizontal predictions are illustrated in Fig. 3(a). Diagonal down left and diagonal down right predictions are illustrated in Fig. 3(b). Based on prediction direction, current block is copied from the pixels of neighboring block in directional prediction. However, prediction can be different depending on whether it goes through low pass filtering. Except vertical and horizontal direction, the remaining direction modes perform low pass filtering before prediction in Intra 4x4 prediction. Intra 8x8 also apply low pass filtering before prediction, but it is different to perform low pass filtering on vertical and horizontal direction.



(a)



(b)

Fig. 3 Example of low pass filtering. (a) Vertical, horizontal prediction, (b) Diagonal down left, diagonal down right prediction

Fig. 3(b) is an example of low pass filtering when diagonal down left prediction is performed. The pixels in current block with diagonal down left direction from D_0 are not directly copied, copied after low pass filtering.

$$C_0 = C_{org} + \Delta q_c,\ D_0 = D_{org} + \Delta q_d,\ E_0 = E_{org} + \Delta q_e \tag{2}$$

Equation (2) means that reconstructed pixels are consisted of two component, original pixel value and quantization error of each pixel. X_{org} means original pixel value and Δq_x means quantization of error (X can be C, D and E). If Δq_d is high enough, it influences accuracy of prediction on pixels with diagonal down left direction from D_0. Low pass filtering is performed to reduce the effect of quantization error of the following:

$$D_* = (¼\cdot C_{org} + ½\cdot D_{org} + ¼\cdot E_{org}) + (¼\cdot\Delta q_c + ½\cdot\Delta q_d + ¼\cdot\Delta q_e). \tag{3}$$

III. PROPOSED METHOD

A. Demerit of low pass filtering in H.264/AVC

In H.264/AVC, low pass filtering is applied to reduce quantization error by taking advantage of weighted average. However, it has a weakness that low pass filtering is equally performed regardless of prediction direction. If a correlation with any direction extends out of the boundary of current block, conventional method to reduce quantization error may reduce the accuracy of prediction in spite of finding direction that can represent current block well. Fig. 5 illustrates the case that conventional method does not work well. Since current 4x4 block in Fig. 5 has strong correlation on direction of diagonal down left, diagonal down left prediction may be selected as best prediction mode. However, coding loss may be occurred on account of inexact prediction. When low pass filtering to be considered prediction direction is performed in the case in Fig. 5, it can be more efficient than conventional method because proposed method may keep original pixel value and reduce quantization error, while conventional method is difficult to keep original pixel value that influences more than quantization error for accuracy of prediction, because of differences between neighboring pixels lain on the center pixel in case of Fig. 5.

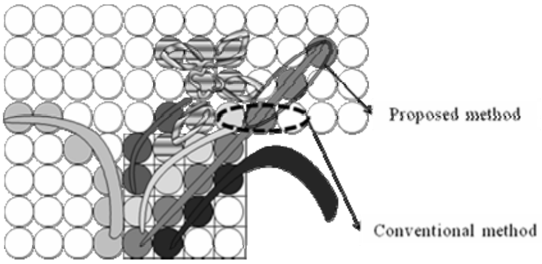


Fig. 5 Problematic case for conventional method

B. Proposed method using weighted average according to prediction direction

It is signaled per block whether low pass filtering is performed or not, in AIS. Since the effect of low pass filtering is different according to characteristic of image, adaptive scheme is applied in AIS. In contrast, a method for reducing quantization error is proposed using weighted average of pixel values according to prediction direction in this paper. Except DC mode, eight prediction modes with direction are used in proposed method. Low pass filtering is applied on the pixels from extended line of prediction direction.

$$X_{*} = (X_0 \cdot \alpha + X_1 \cdot \beta + \dots) \div (\alpha + \beta + \dots) \quad (4)$$

Equation (4) is the weighted average equation where X_0, X_1, α and β denote respectively nearest pixels and nearest pixels of current block except X_0 and weighting factors of X_0 and X_1. Normally, the weighting factor value of pixel that is lain with short distance from current block is bigger than the other because nearest pixel has high spatial correlation with current block in many cases.

$$\alpha \geq \beta \geq \gamma \geq \dots \quad (5)$$

It can be used with multiple lines for weighted average according to prediction direction as shown in Fig. 6. Vertical and horizontal prediction in proposed method is illustrated in Fig. 7(a). Diagonal down left and diagonal down right prediction in proposed method are illustrated in Fig. 7(b).

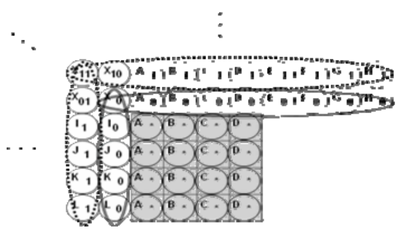
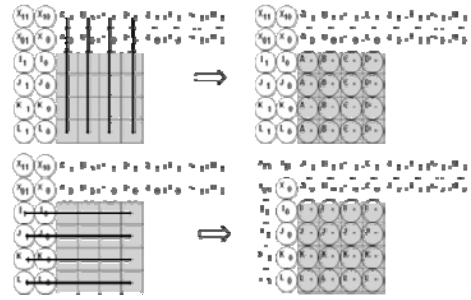
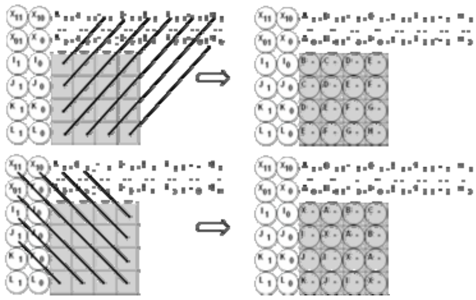


Fig. 6 Pixel candidates for low pass filtering



(a)



(b)

Fig. 7 Example of proposed method. (a) Vertical, horizontal prediction, (b) Diagonal down left, diagonal down right prediction

Since situation is different according to characteristic of image, we use adaptive scheme technique like AIS. For the decision, RDO is used to determine which low pass filtering is used for each macroblock/block by minimizing the following:

$$J = D + \lambda \cdot R_N \quad (6)$$

The variable D and λ is similar with (1) except R_N. Difference between R in (1) and R_N is the existence of flag bit to distinguish method to be used for reducing quantization error.

In addition to the proposed low pass filtering, a threshold condition is given for saving the flag bit. If the difference of predictor between conventional and proposed method is almost small, it can be wasteful to send the flag bit. So when above condition is occurred, encoder does not generate the flag bit. Instead of generating the flag bit, the proposed method is selected for low pass filtering.

In proposed method, one bit flag is signaled in Macroblock (MB) whether proposed method is used or not. If proposed method is used, adaptive scheme is applied in each block(4x4 or 8x8). Otherwise, conventional method is used.

IV. Experimental results

The proposed method is implemented on the reference software jm11.0kta2.2r1[9] and it is compared with H.264/AVC. The proposed method is applied to the Intra 4x4, Intra 8x8 prediction. It is also applied to the Intra 4x4, Intra 8x8 prediction in anchor. The experiments are performed under VCEG common test condition [10] and all the frames are encoded using I-frame coding. Entropy coder is CABAC and RDO is on. Test sequence is selected among sequences that are used in Call for proposal of MPEG and number of frame to be coded is 100. QP is set to 22, 27, 32 and 37. Weighting factor for low pass filtering and threshold in flag skip condition are determined by several experiments. The details of experimental conditions are shown in Table I.

TABLE I
EXPERIMENTAL CONDITION

GOP structure	Only I
Software	Jm11.0kta2.2r1
Entropy coder	CABAC
QP	22, 27, 32, 37
Number of frames	100 frames
Weighting factor	α : 2/3 , β : 1/3
Threshold in flag skip	3

TABLE II
EXPERIMENTAL RESULTS

Resolution	Sequence	AIS BD-bitrate (%)	Proposed BD-bitrate (%)
	BasketballDrill	-0.845	-3.567
832x480	BQMall	-0.916	-1.262
	PartyScene	-0.555	-1.347
Average of 832x480		-0.772	-2.058
	Vidyo1	-0.911	-0.872
1280x720	Vidyo3	-0.984	-1.132
	Vidyo4	-0.739	-0.731
Average of 1280x720		-0.877	-0.911
	BQTerrace	-1.271	-2.034
1920x1080	BasketballDrive	-2.089	-2.373
	Cactus	-0.599	-0.580
Average of 1920x1080		-1.319	-1.662
Overall Average		-0.989	-1.543

Table II shows the comparisons of the experimental results obtained from two experiments using the reference codec, jm11.0kta2.2r1. The average bit saving of AIS is about 0.989%. The best case is about 2.089% in BasketballDrill. On the other hand the average bit saving of proposed method is about 1.543%. It is BasketballDrill sequence for best case, about 3.368%. Table 2 shows that the proposed method can reduce quantization error better than AIS from the experimental result.

V. CONCLUSION

In this paper, we proposed a method to reduce quantization error using weighted average of pixel values according to direction of prediction. Since proposed low pass filtering is applied on pixel of neighboring block according to direction of prediction, it can reduce quantization error effectively. In addition to low pass filtering, using threshold condition can reduce additional flag bit to distinguish method of low pass filtering. Bit rate reduction between 0.580% and 3.567% are shown for experimental results. We can achieve the average bit-rate reduction of 1.534% by applying the proposed method.

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Kibaek Kim received his B.S and M.S degree in the Department of Information and Communication Engineering from Sejong University, Korea, in 2008 and 2010, respectively. He is currently a Ph.D student in the Department of Electronics and Computer Engineering, Hanyang University. His research interests fall under the umbrella of image processing, video coding standards such as H.264/AVC, HEVC and fast motion estimation.

Dongjin Jung received a B.S degree in the Department of Electronics Convergence Engineering from Kwangwoon University, Korea, in 2010. He is currently a M.S student in the Department of Electronics and Computer Engineering, Hanyang University. His research part concerns about video coding standards such as H.264/AVC, HEVC and fast motion estimation.

Jinik Jang received the B.S degree in the Department of electronic engineering from Hanyang University, Seoul, Korea, in 2010. He is currently M.S. student in electronics and computer engineering, Hanyang University. His research interests include motion estimation and compensation algorithms, video coding standards such as H.26x and HEVC, and image enhancement.

Jechang Jeong received a B.S. degree in Electronic Engineering from Seoul National University, Korea, in 1980, an M.S. degree in Electrical Engineering from the Korea Advanced Institute of Science and Technology in 1982, and a Ph.D. degree in electrical engineering from the University of Michigan, Ann Arbor, in 1990. From 1982 to 1986, he was with the Korean broadcasting System, where he helped develop teletext systems. From 1990 to 1991, he worked at the University of Michigan, Ann Arbor, as a Postdoctoral Research Associate, where he helped develop various signal processing algorithms. From 1991 through 1995, he was with the Samsung Electronics Company, Korea, where he was involved in the development of HDTV, digital broadcasting receivers, and other multimedia systems. Since 1995, he has conducted research at Hanyang University, Seoul, Korea. His research interests include digital signal processing, digital communication, and image/audio compression for HDTV and multimedia applications. He has published over 30 technical papers. Dr. Jeong received the “Scientist of the Month” Award in 1998, from the Ministry of Science and Technology of Korea. He was also honored with a government commendation in 1998, from the Ministry of Information and Communication of Korea.