# Intra filtering based on correlation of prediction directions

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***Abstract*— To reduce spatial redundancies, H.264/AVC adopts intra prediction technique. It uses pixels from neighboring coded block for predicting current block. For improving coding efficiency, this paper presents an efficiency coding method for H.264/AVC intra prediction. This paper proposes an intra filtering based on correlation of prediction directions. Proposed method considers direction of prediction and correlation between blocks. After checking block mode and direction of neighboring blocks, different intra filtering is used according to the information of neighboring blocks instead of conventional method. Adaptive scheme is used to determine optimal mode. Simulation results report that the proposed method yields an average of 1.676 % bit rate reduction over the H.264/AVC.**

***Index Terms*—H.264/AVC, Intra coding, Intra filtering**

## I. INTRODUCTION

H.264/AVC video standard is flexible and offers numerous tools to support a range of applications with low- and high-bitrate requirements. Compared with MPEG-2 video, the H.264/AVC gives perceptually equivalent video at one-third to one-half of the MPEG-2 bitrates. The bitrate gains are the results of combination of encoding tools. These gains come with a significant increase in encoding and decoding complexity. H.264/AVC uses the same hybrid coding approach: motion-compensated transform coding, directional prediction in intra coding, motion estimation/motion compensation (ME/MC) based on quarter-pel accuracy with variable block sizes [1][2].

H.264/AVC employs directional spatial prediction for intra prediction. It predicts target block to be coded from previously encoded upper or left pixels of neighboring blocks. H.264/AVC supports three types with various block size for intra prediction, i.e., Intra 4x4, Intra 8x8 (FRExt-only [3]), and Intra 16x16. Several predefined prediction modes are served as candidates, and then the rate distortion optimization (RDO) procedure will choose the most optimal mode for the block. This improves coding efficiency of intra coding in comparison with previous video/image coding standards.

There are candidate modes selected by the encoder of H.264/AVC, including DC prediction mode suitable for smooth region and the other directional prediction modes for corresponding texture region. Various candidates improve the prediction accuracy. Before target block is predicted by using prediction candidates, low pass filtering is applied on pixels on neighboring blocks. Since low pass filtering in H.264/AVC is fixed regardless of image characteristic, it is difficult to predict block on region that is not proper to use conventional filtering. This paper investigates an efficient method for better filtering of intra prediction. The correlation between target block and neighboring blocks is firstly checked. Then intra filtering method is applied according to the research.

The rest of this paper is organized as follows. Section 2 and section 3 describe the conventional and proposed method respectively. Simulation results are presented in section 4 and conclusions are drawn in section 5.

## II. LOW PASS FILTERING IN H.264/AVC

To achieve coding efficiency, H.264/AVC supports three MB modes for luma components: Intra 4x4, Intra 8x8, and Intra 16x16. They have the block size as indicated by the name. For Intra 16x16, four prediction modes, vertical, horizontal, DC and plane mode are employed. For the intra 4x4 and intra 8x8, eight directional prediction modes are developed, as shown in Fig. 1, except DC mode. For determining best prediction mode of target block, encoder uses a Lagrangian cost function which considers both bit rate and distortion of the block like following:

$$J = D + \lambda \cdot R \quad (1)$$

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

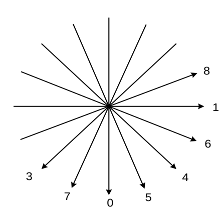
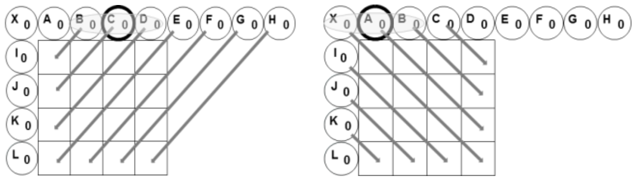



Fig.1. Prediction directions of Intra 4x4 and Intra 8x8

For better coding performance, low pass filter is applied to boundary pixels of the neighboring block, which has been coded in same picture, in H.264/AVC. Since the coded areas have quantization error by lossy coding. H.264/AVC apply low pass filter with 3-tap (0.25, 0.5, 0.25) on the neighboring pixels data. Therefore, the prediction accuracy can be improved. Figure 2 shows an example of low pass filtering for diagonal down left and right prediction.




(a) (b)

Fig.2. Examples of low pass filtering: (a) Intra 4x4 diagonal down left, (b) Intra 4x4 diagonal down right

There are two kind of low pass filtering. When upper and left neighboring blocks are available, filtered boundary pixels of neighboring are derived by

$$p'[x,y] = \frac{p[x-1,y] + 2 \times p[x,y] + p[x+1,y]}{4} \quad (2)$$

$$p'[x,y] = \frac{p[x,y-1] + 2 \times p[x,y] + p[x,y+1]}{4} \quad (3)$$

$$p'[x,y] = \frac{p[\lceil x-1 \rceil, y] + p[\lfloor x+1 \rfloor, y]}{2} \quad (4)$$

$$p'[x,y] = \frac{p[x, \lceil y-1 \rceil] + p[x, \lfloor y+1 \rfloor]}{2} \quad (5)$$

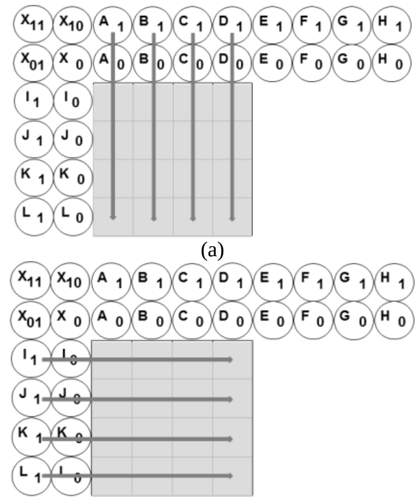
where $p'[x,y]$ denotes filtered sample of pixel position $p[x,y]$ of Fig. 3 and $\lceil a \rceil$ means the smallest integer among values over than 'a' and $\lfloor a \rfloor$ means the biggest integer among values less than 'a'. In some direction, only integer pixels of neighboring block are used to predict current block, such as vertical, horizontal, diagonal down right, and diagonal down left. It is relevant with Eq. (2) and (3). In direction like vertical right and vertical left, however, fractional pixel to be made by interpolation in addition to integer pixel are used to predict target block for some pixels. Equation (4) and (5) is included to the case. The filtering process is adopted in the decoder side identically, and there is no side information for the process. However, it is difficult to get the effect of filtering if there is big difference between pixels, since it performs low pass filtering regardless of prediction direction.

## III. PROPOSED ALGORITHM

Proposed algorithm is based on adaptive scheme to select one among filtering candidates like Adaptive intra smoothing (AIS) [4]. Since conventional process is not optimum, so it may occur negative effects in some region according to image characteristic. For solving the problem, the filtering process is implemented adaptively by a decision rule. For the decision, it is used by RDO. One bit flag is sent to the decoder for distinguishing which filtering is used. There are two candidates for filtering. One is the conventional filter in H.264/AVC and the other is proposed filter to consider prediction direction. Low pass filtering is applied on the pixels from extended line of direction.

$$X^* = ( X_0 \cdot \alpha_0 + X_1 \cdot \alpha_1 + \dots ) / ( \alpha_0 + \alpha_1 + \dots ) \quad (6)$$

Equation (6) means the weighted average where X, α, and subscript denote respectively pixel value, weighting factor, and distance index. Multiple lines of neighboring block can be used for weighted average like Eq. (6). After filtering, $X^*$ is used to predict pixels on extended line, with the direction, from $X_0$. Vertical and horizontal in proposed algorithm are illustrated in Fig. 3.




(b)

Fig.3. Proposed intra filtering: (a) Intra 4x4 vertical, (b) Intra 4x4 horizontal

We consider the correlation between target block and neighboring blocks. If there is a successive directionality between blocks as shown in Fig. 4, pixels laid on the particular direction has high correlation. For reducing quantization error that influences accuracy of prediction, many pixels of neighboring block for low pass filtering are used in the proposed method if it is the situation like Fig. 4. After checking the continuity, low pass filtering with different tap is applied according to the research before intra prediction. As shown in Fig. 5, we can see the case of successive directionality between blocks.

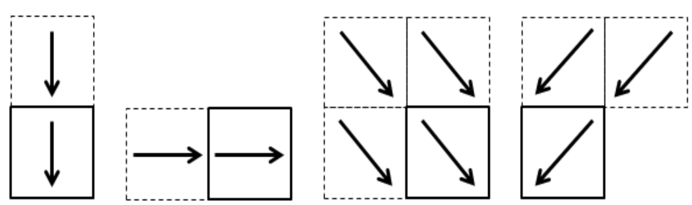


Fig.4. Examples of block with successive directionality.

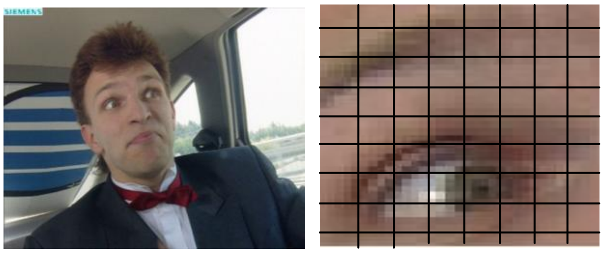


Fig.5. Successive directionality between blocks

According to MB mode of neighboring block, different tap is applied. If there is vertical continuity between upper block and target block and the MB mode of upper block is Intra 4x4, intra filtering with 2-tap is applied. If there is horizontal continuity between left block and target block and the MB mode of left block is Intra 16x16, intra filtering with 4-tap is applied.

## IV. Simulation Results

The proposed method was implemented into the H.264/AVC reference software JM16.0 [5] and evaluated the performance of test sequence with various sizes. The test conditions are set as follows.

TABLE I. TEST CONDITIONS OF PROPOSED ALGORITHM

| | |
|---|---|
| Profile | High, All intra |
| Entropy coder | CABAC |
| Number of frame | 50 |
| QP values | 22, 27, 32, 37 |
| RDO | On |

TABLE II. TEST CONDITIONS OF PROPOSED ALGORITHM

| | $\alpha_0$ | $\alpha_1$ | $\alpha_2$ | $\alpha_3$ |
|---|---|---|---|---|
| Default | 0.667 | 0.332 | 0 | 0 |
| I4MB | 0.625 | 0.375 | 0 | 0 |
| I8MB | 0.571 | 0.285 | 0.143 | 0 |
| I16MB | 0.5 | 0.25 | 0.15 | 0.1 |

The filter coefficient of the situation that has the continuity between target block and neighboring block is set according to MB mode of neighboring block and continuity between blocks as shown in Table. II. Coefficients on Table. II are represented in Eq. (6). Average PSNR gain and bit reduction rate are calculated based on the BD-PSNR [6]. Table III shows the simulation results. The average bit saving is 1.676 % and the average PSNR gain is 0.098 dB for various test sequences in high profile. The bit-saving is 4.066 % and the average PSNR gain is 0.224 dB in Foreman sequence for best case. From the rate-distortion (RD) curves shown in Fig. 6 and Fig. 7, the proposed algorithm improves the H.264/AVC performance.

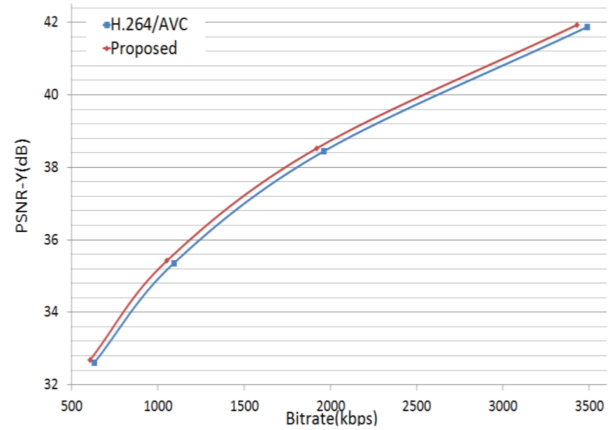



Fig.6. RD curves for Foreman sequence

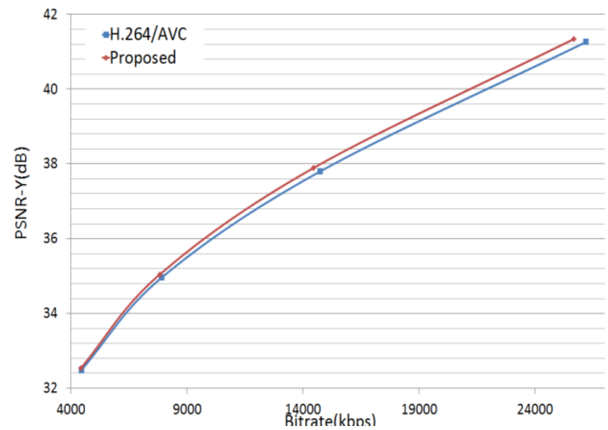



Fig.7. RD curves for BasketballDrill sequence

TABLE III. EXPERIMENTAL RESULTS

| Sequence | | Frame rate (Hz) | Coding efficiency BD-bitrate (%) | |
|---|---|---|---|---|
| | | | *BD-bitrate (%)* | *BD-PSNR (dB)* |
| CIF | Foreman | 30 | -4.066 | 0.224 |
| | Akiyo | 30 | -1.116 | 0.074 |
| | Container | 30 | -1.128 | 0.073 |
| | Paris | 30 | -1.068 | 0.094 |
| | **Average of CIF** | | **-1.845** | **0.116** |
| WVGA | BasketballDrill | 50 | -3.162 | 0.158 |
| | BQMall | 60 | -1.281 | 0.081 |
| | PartyScene | 50 | -1.093 | 0.087 |
| | **Average of WVGA** | | **-1.846** | **0.109** |
| Full HD | BQTerrace | 60 | -1.963 | 0.127 |
| | BasketballDrive | 50 | -1.346 | 0.035 |
| | Cactus | 50 | -0.530 | 0.021 |
| | **Average of Full HD** | | **-1.280** | **0.061** |
| **Overall Average** | | | **-1.676** | **0.098** |

## V. Conclusion

In this paper, we propose an intra filtering method based on correlation of prediction directions for improving accuracy of prediction. Low pass filtering according to image characteristic is applied and filter tap is determined in terms of continuity between blocks and MB mode of neighboring block. Bit rate reduction between 0.530 % and 4.066% are shown in simulation results. The average bit saving is 1.676 % and the average PSNR gain is 0.098 dB for various sequences. From the results, the proposed algorithm improves coding efficiency.

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