BLOCK BASED EXTRA/INTER-POLATING PREDICTION FOR INTRA CODING

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ABSTRACT

In this paper, we propose an efficient intra coding method. The method involves adding an extra/inter-polating prediction method to the conventional H.264/MPEG-4 AVC (H.264) intra prediction method. The proposal consists of two parts. One is to change the sub-block coding order in macroblock (MB). The bottom-right sub-block in MB is predicted using the reference pels on the upper and left side of the sub-block firstly. After that, the other sub-blocks are predicted using not only the reference pels on the upper and/or left side but also ones on the bottom and/or right side of each sub-block. The other part is to use an intra bi-directional prediction method which can use the interpolation of the prediction from upper/left pels and the prediction from bottom/right pels. Experimental results show that our method improves bit reduction by up to 7.7% at the same PSNR compared to H.264.

***Index Terms*—** video coding, image coding, prediction methods

1. INTRODUCTION

H.264/MPEG-4 AVC (H.264) [1] is the newest video coding standard developed by ITU-T and ISO/IEC. H.264 can achieve much higher coding efficiency than the conventional standards such as MPEG-1/2/4 and H.261/263. In the inter predictive coding, H.264 adopts the bi-prediction method by changing the frame coding order and employs it for B-Slices (B-Pictures) as well as MPEG-1/2/4, which improves efficiency of the inter coding. In addition, the Weighted Prediction method [1] is adopted in H.264 in order to compensate the signal level transition in fade-in/out or dissolve scenes.

On the other hand, in intra coding, H.264 adopts a new intra prediction method to reduce spatial redundancy between adjacent sub-blocks. However, the current sub-block cannot refer to the pels on the right side or on the bottom side of the current sub-block since H.264 employs the raster-scanned coding order for sub-blocks in MB. Therefore, the current sub-block cannot utilize the interpolation of the prediction from upper pels and the prediction from bottom pels. In a similar way, it cannot utilize the interpolation of the prediction from left pels and the prediction from right pels.

In this paper, in order to improve coding efficiency for intra coding, we propose a block based extra/inter-polation method by changing the sub-block coding order in MB. A bidirectional prediction method is introduced as one of the interpolation methods.

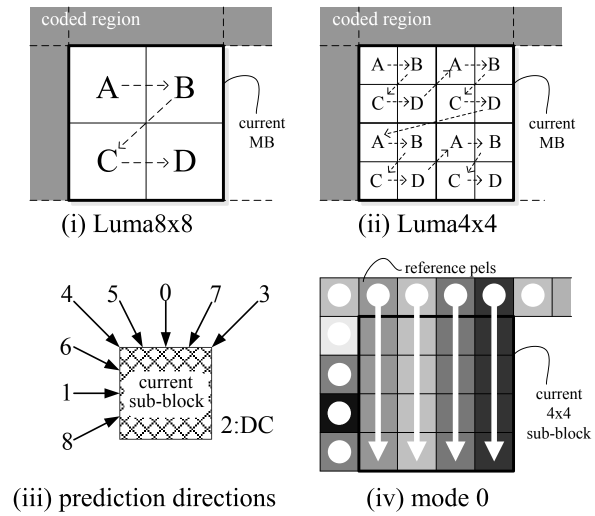


Fig.1 Intra prediction of H.264

2. INTRA PREDICTION IN H.264/AVC

In this section, we describe the intra prediction method for the 8x8 sub-block prediction for luminance component (Luma8x8) and 4x4 sub-block prediction for luminance component (Luma4x4) as specified in H.264 High Profile (HP). H.264 HP utilizes the raster-scanned sub-block coding order of Luma8x8 and Luma4x4 as shown by **Fig.1**(i) and (ii), respectively. The coding order of the sub-blocks is the raster-scan order from upper-left side to bottom-left side in the MB, which corresponds to "A→B→C→D" order in **Fig.1**(i) and (ii). The coded sub-block is decoded immediately, and then it is used as reference pels for the succeeding coding sub-blocks. In addition, nine prediction candidates which consist of eight directional prediction modes and a DC prediction mode are specified, which are shown in **Fig.1**(iii). When one of the prediction modes is selected for the current sub-block, the prediction values are generated by extrapolation using the already coded pels surrounding the current sub-block. For example, the mode 0 in Luma4x4 is shown in **Fig.1**(iv). The 16 pels of the current 4x4 sub-block are predicted by copying pels on the upper side of the current 4x4 sub-block according to the direction of the mode 0, that is, in the vertical-down direction.

Considering causality, the pels on the right side or the bottom side of the current sub-block cannot be used since they have not been coded yet. In addition, it is insufficient to predict complicated texture regions since only one mode is applicable for each sub-block in H.264.

3. BLOCK BASED EXTRA/INTER-POLATING PREDICTION

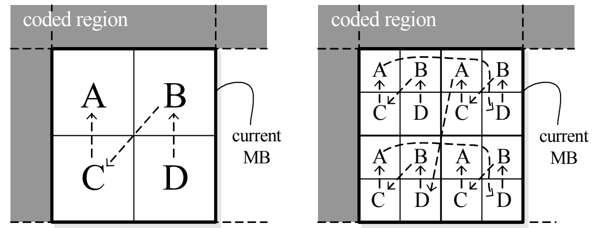
In this section, we propose the Block based Extra/Inter-polating Prediction (BEIP) method. The main features of the BEIP method has are as follows:

- changing the sub-block coding order and adding more prediction directions
- adaptive selection of the sub-block coding order
- introducing of bidirectional prediction by combining two prediction directions

3.1 Sub-block coding order and prediction directions

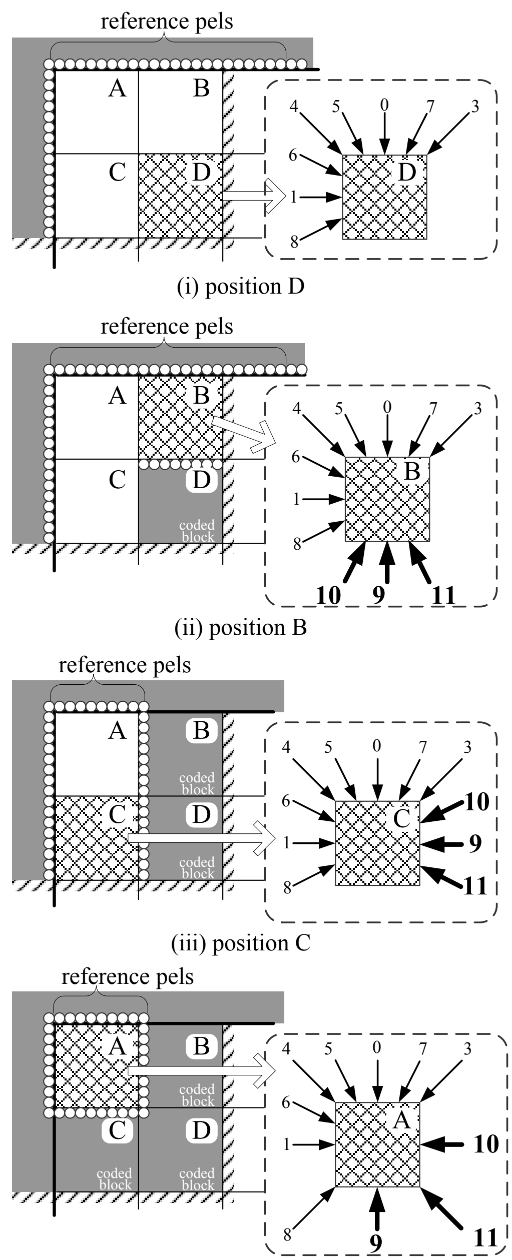
In the proposed method, the sub-block coding order in MB is different from the one for H.264. When Luma8x8 prediction is performed, the sub-blocks are coded in the order of “D→B→C→A” as shown in **Fig.2**(i). In the case of Luma4x4, the sub-block order of Luma8x8 is performed in the unit of 8x8 block as shown by **Fig.2**(ii).

The prediction directions are not to be the same for each sub-block in MB since the available reference pel positions for the current sub-block are different from each other. Concrete prediction directions for each sub-block position of Luma8x8 are shown in **Fig.3**. In this figure, the sub-block marked with the checked pattern is the current sub-block and the regions marked with gray are already coded sub-blocks. White circles show the reference pels for the current sub-block. Firstly, sub-block D located in the bottom-right sub-block is coded. In this case, the prediction directions are identical with H.264’s ones (**Fig.4**(i)). Secondly, sub-block B located in the upper-right sub-block is coded. Since the sub-block D has already been coded, the prediction modes (mode 9, mode 10 and mode 11) are added. They correspond to vertical-up direction using reference pels in sub-block D (**Fig.4**(ii)). Thirdly, the sub-block C is coded in a similar fashion. Since the right side of the current MB has been coded, the prediction modes corresponding to horizontal-left direction are added (**Fig.4**(iii)). Finally, the sub-block A is coded. In this case, there are reference pels surrounding the sub-block A since the sub-blocks B, C, and D have been coded. Therefore, the prediction modes corresponding to horizontal-up (mode 9), vertical-left (mode 10) and diagonal-up-left (mode 11) directions are added (**Fig.4**(iv)). In the case of Luma4x4, the prediction is performed in the same prediction directions of Luma8x8. In general, the change of the sub-block coding order decreases prediction accuracy of sub-block D due to the increase of spatial distance between the current and reference pels. On the other hand, prediction accuracy in the other sub-block can be improved since the prediction modes



(i) Luma8x8 (ii) Luma4x4

Fig.2 Sub-block coding order of proposed method



(i) position D

(ii) position B

(iii) position C

(iv) position A

Fig.3 Sub-block order and prediction directions of proposed method

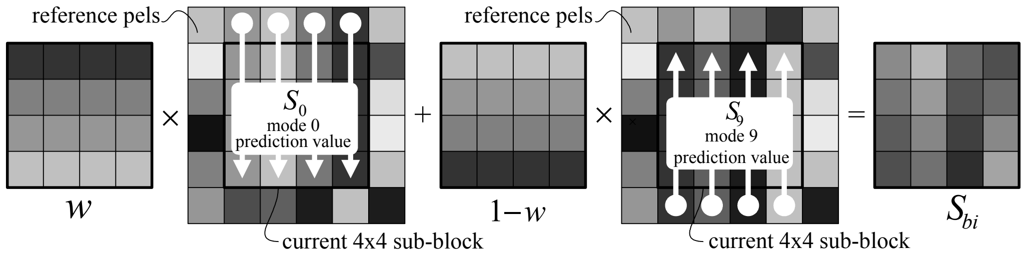


Fig.4 Bidirectional intra prediction

using the reference pels on the right side and/or on the bottom side of the current sub-block are available.

3.2 Adaptive selection of the sub-block coding order

The proposed sub-block coding order can make coding efficiency of the three sub-blocks (A, B, and C) better as explained above. However, in the case that the three sub-blocks correlate weakly with the reference pels on the bottom/right side of the current sub-block, it may be less effective than the conventional order as shown in **Fig.1**(i) and (ii). In this case, the coding efficiency may decrease due to increase of additional mode information for the prediction modes. Therefore, in this paper, we propose to select the sub-block coding order MB-by-MB from either the raster-scanned order or the proposed order adaptively.

In order to decide the best sub-block coding order, the Rate-Distortion Optimization method [2] is used in the encoder. The cost function J is shown as follows:

$$J = D + \lambda R, \qquad (1)$$

where, D is coding distortion between the original image and the local decoded image, and R means generated bits. λ is the Lagrange parameter. The best sub-block coding order type (raster-scanned sub-block coding order or proposed sub-block coding order) is transmitted to the decoder for each MB.

3.3 Bidirectional intra prediction

Moreover, the bidirectional prediction method [3] is introduced. In this method, the prediction value is generated in combination with two kinds of the intra prediction modes at each sub-block. The bidirectional prediction value S_{bi} is calculated as follows:

$$S_{bi} = w \cdot S_P + (1-w) \cdot S_Q, \qquad (2)$$

where S_P and S_Q are the prediction values with prediction mode P and mode Q ($P, Q = 0, 1, 2, \cdots$) at the pel, respectively. w is a prediction coefficient of prediction mode P, and is set implicitly at each pel using the spatial auto-correlation model. The auto-correlation model is designed according to spatial distance of target pel to reference pel. An example of Luma4x4 with Eq.(2) in sub-block A is shown in **Fig.4**. This figure shows that the matrix of w s is illustrated by monochrome, and if the color at each pel is black, it shows that w is large. Bidirectional prediction values are generated using weighted combination of prediction values of mode 0 and mode 9.

If the angular difference between mode U and mode V is 180 degrees, such as a combination of mode 1 and mode 10, mode 4 and mode 11, or mode 3 and mode 8 as shown in **Fig.3**(iv), it is the functional equivalent of the interpolation.

4. EXPRIMENTAL RESULTS

In order to evaluate the coding efficiency of BEIP, we performed coding experiments using various video sequences. The sequences in QCIF, CIF and 720p60 formats are tested. **Table.1** shows experimental conditions. The bit reduction (Δbitrate) is calculated based on the BD-PSNR described in [4]. **Table.2** shows the experimental results. It shows that BEIP improves the bit reduction by up to 7.7% at the same PSNR. The rate-distortion curves for the sequence Raven (720p60) are shown in **Fig.5**. The curves show that the proposed method outperforms H.264 in all of these bitrates.

Fig.6 shows the averaged selection ratio of sub-block coding order in all MBs for each sequence with QP range from 16 to 28. It is observed that about 50 % of the MBs are coded using the proposed sub-block coding order, and it tends to achieve the higher coding efficiency if the ratio of the proposed sub-block coding order is higher. Therefore it is confirmed that an introduction of the proposed sub-block

Table.1 Experimental conditions

Coding Structure	IIII... (I-Slice Only)
BEIP	On (proposed) / Off (H.264)
Entropy Coding	CABAC
RD Optimization	Used
Number of Coding Frames	60
Quantization Parameter	16, 20, 24, 28

Table.2 Experimental results

Sequence	Size Frame Rate	ΔBitrate (%)
Foreman	QCIF (176x144) 15 fps	4.58
Silent		5.34
Stefan		5.46
Flower	CIF (352x288) 30 fps	6.67
Mobile & Calender		4.82
Tempete		5.44
City	720p60 (1280x720) 60 fps	4.23
Night		4.86
Raven		7.68
Average	---	**5.42**

coding order makes the coding efficiency improve. **Fig.7** shows the prediction accuracy and bit reduction of each sub-block's position (A, B, C, and D) in MB for Raven. In this figure, the bar graph with white shows the prediction error (SAD: Sum of Absolute Difference) reduction and the bar graph with gray shows the bit reduction achieved by BEIP. The values are the ratios compared to H.264 when MB is applied to the proposed sub-block coding order. In the case of sub-block D, it shows that both SAD and generated bits are increased due to the increase of spatial distance between the current and reference pels. On the other hand, in other sub-blocks in MB, SAD and generated bits are reduced by 16-19% and 3-5%, respectively. This is because both the new prediction directions from the bottom/right reference pels which cannot be used in H.264, and the block-based interpolation method are effective. SAD reduction by 5.1% and bit reduction by 2.2% are achieved over whole MBs. Lastly, prediction images for luminance component using (i) H.264 and (ii) the proposed method are shown in **Fig.8**, respectively. This figure shows that prediction accuracy of the proposed method is higher than H.264 in the same generated bits. In particular, the complicated regions such as a figure of calendar and the calendar date are predicted efficiently.

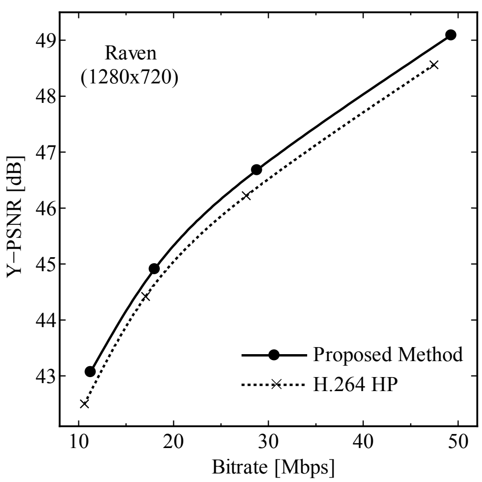


Fig.5 Rate-Distortion curve

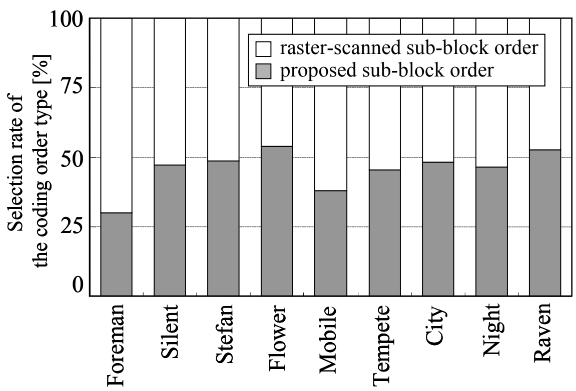


Fig.6 The selection rate of sub-block order type (without 16x16 luminance prediction)

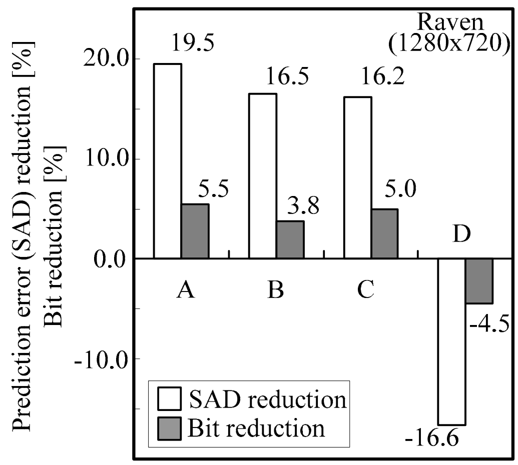
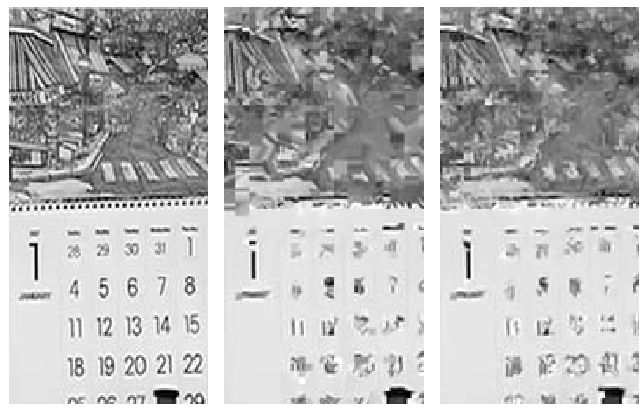


Fig.7 Coding efficiency of each sub-block's position in MB (QP=20)



Original image (trimmed) | (i) H.264 (290.2 kbits) | (ii) Proposed (289.8 kbits)

Fig.8 Comparison of prediction images (Mobile & Calender, Frame #22, QP=24)

5. CONCLUSIONS

In this paper, a new prediction method is proposed to improve coding efficiency for intra prediction. The method includes an extra/inter-polating prediction method in which sub-block coding order is changed in MB. Experimental results show that our method improves the coding efficiency by up to 7.7% at the same PSNR compared to H.264.

6. REFERENCES

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