A Non-parametric Fast Block Size Decision Algorithm for H.264/AVC Intra Prediction

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Abstract—The H.264/ AVC video coding standard supports the intra prediction with various block sizes for luma component and a 8x8 block size for chroma components. This new feature of H.264/AVC offers a considerably higher improvement in coding efficiency compared to previous compression standards. In order to achieve this, H.264/AVC uses the Rate-distortion optimization (RDO) technique to select the best intra prediction mode for each block size, and it brings about the drastic increase of the computation complexity of H.264 encoder. In this paper, a fast block size decision algorithm is proposed to reduce the computation complexity of the intra prediction in H.264/AVC. The proposed algorithm computes the smoothness based on AC and DC coefficient energy for macroblocks and compares with the non-parametric criteria which is determined by considering information on neighbor blocks already reconstructed, so that deciding the best probable block size for the intra prediction. Also, the use of non-parametric criteria makes the performance of intra-coding not be dependent on types of video sequences. The experimental results show that the proposed algorithm is able to reduce up to 30% of the whole encoding time with a negligible loss in PSNR and bitrates and provides the stable performance regardless types of video sequences.

Index Terms—Block size decision, H.264/AVC, Intra Prediction, Non-parametric criteria

I. INTRODUCTION

The H.264/AVC video coding standard has been developed by JVT(Joint Video Team) formed by the ITU-T VCEG(Video Coding Experts Group) and the ISO/IEC MPEG(Moving Picture Experts Group)[1]. H.264/AVC offers a significant performance improvement over the previous video coding standards such as H.263++ and MPEG-4, etc. H.264/AVC provides gains in coding efficiency of up to 50% over a wide range of bitrates and video resolutions compared to previous standards[2,3]. This is accomplished mainly due to the adoption of new coding technologies such as intra prediction coding, quarter-pels motion estimation compensation, variable block size coding, multiple reference frames, 4x4 integer transform, in-loop deblocking filter, CABAC(content adaptive binary arithmetic coding), etc[2]. Specially, among many new features, the intra prediction in spatial domain is regarded as one of the important features that contribute to the success of H.264/AVC.

H.264/AVC supports the intra prediction with various block sizes. For coding the luma component, a 16x16 macroblock may be predicted as a whole, or it is divided into sixteen 4x4 blocks and each 4x4 block is predicted individually. In H.264/AVC FREXt (Fidelity Range Extension), a macroblock may also be predicted as individual 8x8 blocks[4]. The intra prediction for the chroma components uses only 8x8 block size. And, H.264/AVC uses Rate-Distortion Optimization(RDO) technique to obtain the best result maximizing visual quality and minimizing bitrates. To choose the optimal intra prediction mode, the standard H.264 encoder uses the full search method which calculates the RDcost(Rate Distortion cost) of every possible mode and chooses the mode having the minimum cost. Thus, the computation complexity is extremely increased compared to previous standards, so it makes H.264/AVC difficult for applications with low computational capability, such as mobile devices[5,6].

To reduce the computation complexity of the intra prediction in H.264/AVC, a variety of fast intra prediction algorithms have been proposed for the last few years [5,6,7,8,9,10]. Among the fast algorithms, some algorithms early choose the proper intra-coding block size using the smoothness of blocks, removing the computation load due to the intra prediction for unlikely block sizes[7,8,9,10]. But, these algorithms mostly use the smoothness thresholds being to be

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determined by experiments to decide the most probable block size, and accordingly the performance of these algorithms would be dependent on the types of video sequences. This is, the parametric fast algorithms may generate low performance on visual quality or bitrates for some types of video sequences. This paper proposes a novel fast block size decision algorithm based on the block smoothness and the correlation between neighboring blocks without using parameters such as empirically given thresholds for the intra prediction in H.264/AVC.

The proposed algorithm is based on the relation between the intra-coding block size and the block smoothness and the correlation of intra prediction modes between neighbor blocks. In the proposed algorithm, the normalized ratio of AC and DC coefficient energy is used as a measure of the block smoothness, and the intra-coding block size is decided according to whether the ratio is high or low. The decision criterion is selected non-parametrically using the intra-coding block sizes and the smoothness of neighbor blocks, so that excluding the dependency of the performance of intra-coding to types of video sequences due to the use of parameters. One restriction in this paper is that since most profiles of H.264/AVC don't support intra 8x8 prediction for luma component[8,10], only intra 4x4 and intra 16x16 predictions are considered. Experiment results show that the proposed algorithm can speed up almost 30% of encoding time for encoding an all I-frame sequences with a negligible loss in PSNR and bitrates compared to the full search method.

The rest of this paper is organized as follows. In Section II, we will first introduce the intra prediction algorithm of H.264/AVC and then review the previous works. Section III presents the proposed algorithm. Then, Section IV shows the experimental results. Finally, conclusions are given in Section V.

II. RELATED WORKS

In H.264/AVC, for luma component, three types of intra prediction are defined according to the intra-coding block size: 16x16, 8x8 and 4x4, and for chroma components, only the 8x8 intra prediction is defined. In the intra prediction of luma component, 9's directional intra prediction modes are used for the 4x4 and 8x8 intra predictions as illustrated in Table 1. Fig. 1 shows 8's prediction modes designed in a directional manner for 4x4 and 8x8 blocks except a DC prediction mode numbered as mode 2. In Fig.2, 16 pixels labeled from a to p are pixels of a 4x4 block belonging to a macroblock to be coded, and the pixels A to M selected from the neighbor blocks being already reconstructed are used in the computation of predictions for pixels from a to p. Each prediction mode corresponds to a spatially-dependent linear combination of reconstructed adjacent pixels generating a prediction of each input pixel. For example, samples a and d are predicted respectively by round($4I+2M+4A$) and round ($4B+2C+4D$) in mode 4, and also by round($2I+2J$) and round($4J+2K+4L$) in mode 8. In mode 2(DC), all pixels from a to p are predicted by an average of adjacent pixels, $(A+B+C+D+I+J+K+L)/8$. The 8x8 intra-prediction for luma component is preformed in the same way but uses adjacent 25 pixels to predict the 8x8 sub-block.

Table 1 Intra prediction modes for 4x4 and 8x8 sub-blocks of luma component

Mode num.	Type of intra prediction mode
0	Vertical
1	Horizontal
2	DC
3	Diagonal-down-left
4	Diagonal-down-right
5	Vertical-right
6	Horizontal-down
7	Vertical -left
8	Horizontal-up

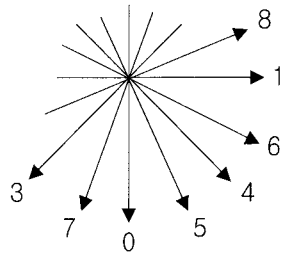

Fig. 1 Prediction directions

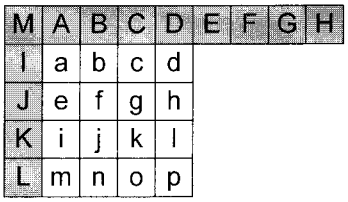

Fig. 2 Target and adjacent pixels for intra 4x4 prediction

The 16x16 intra prediction modes for luma component are selected in relatively homogeneous area and four prediction modes are supported as listed in Table 2 comprising of the DC, vertical, horizontal and plane predictions. These modes are specified similar to prediction modes supported in the 4x4 intra prediction except the plane prediction mode. The

plane prediction mode uses weighted combination of horizontal and vertical adjacent pixels. For chroma components, there are 4 prediction modes applied to the two 8x8 chroma blocks (U and V), which are very similar to the 16x16 intra prediction modes for luma component such as DC(Mode 0), horizontal (Mode 1), vertical (Mode 2), and plane (Mode 3).

Table 2 Intra prediction modes for a 16x16 block of luma component

Mode num.	Type of intra prediction mode
0	Vertical
1	Horizontal
2	DC
3	Plane

The intra prediction based on the full search method using RDO technology in H/264/AVC brings about the extremely high computation loads, and to reduce the overload, several approaches have been proposed for the fast intra prediction processing[5,6,7,8,9,10]. In [5] and [6], the local edge direction in a macroblock is calculated by using the edge directional histogram and the simple edge masks, respectively, and a candidate mode group is determined by selecting the probable prediction modes using the edge direction information. The algorithms was able to reduced the computation load by performing only the RDO computation on the candidate modes, but had to consider all block types for luma component.

In a different way from [5] and [6], in [7], the smoothness of a macroblock is used to select the probable intra-coding block size, reducing the computation load required by unlikely block sizes. The algorithm used the normalized ratio of AC and DC coefficient energy as the block smoothness and decided the probable block size by comparing with the threshold given by experiments. In [8] as an improved algorithm of [5], a probable block size is decided by comparing the amplitude of the edge histogram cell corresponding to the primary prediction mode and the given threshold. In [9], two primary amplitude thresholds and SATD of the 16×16 luma block are exploited to judge 4×4 or 16×16 block size for the intra prediction. In [10], the boundary difference values between inner sub-blocks in a macroblock is calculated and compared with the given threshold to decide the probable block size for intra prediction.

The previous works mostly used parameters such as empirically given thresholds to decide the probable block size or prediction modes, and it makes the performance of intra-coding be dependent on types of video sequences. To exclude the performance dependency, this paper proposes a new fast block type decision algorithm that non-parametrically decides the most probable block size by considering information on neighbor blocks already reconstructed.

III. PROPOSED FAST BLOCK SIZE DECISION ALGORITHM

This paper proposes the non-parametric fast block size decision algorithm that decides the best probable block size for the intra-coding to reduce the computation complexity of the intra prediction in H.264/AVC. The use of parameters such as fixed thresholds in the intra prediction makes the performance of intra-coding be dependent on types of video sequences, and to produce the stable performance of intra-coding regardless of video sequence types, the fast intra prediction algorithms have to consider the characteristics of a vide sequence's own in addition to the general features on the intra-coding in H.264/AVC. The proposed algorithm explores two features on the intra-coding observed in previous works[5,6,7]: (i) the intra-coding block size is highly dependent on the smoothness of the block, and (ii) the best intra-coding mode of the current block is highly correlated to its neighbor blocks.

By the first feature, it is known that a smooth block tends to use the large intra-coding block size while a complex block tends to use the small one. To decide an intra-coding block size using this feature, first, the proposed algorithm adopts the normalized ratio of AC and DC coefficient energy presented in the previous work[7] as a measure for the smoothness of a block. It's because the smoothness of a block is highly related to the frequency distribution represented by AC coefficients in the frequency domain and AC and DC coefficient energy are able to be computed easily and approximately in the pixel domain.

In this paper, to ease the calculation of AC/DC ratio, the 8x8 block is chosen as the basic unit by down-sampling from a 16x16 macroblock, since the 8x8 block reflects sufficiently the frequency distribution of the original block and 8x8 DCT coefficients are effectively calculated in the transform domain. The down-sampling is conducted by selecting one per two pixels in the vertical and horizontal directions. In the 8x8 block, AC and DC coefficient energy is easily computed even in the pixel domain, and the following simple method is used to calculate the AC and DC coefficient energy:

$$DC\_energy = \frac{1}{8\times 8}\left(\sum_{i=0}^{7}\sum_{j=0}^{7} a_{ij}\right)^2 \quad (1)$$

$$AC\_energy = \left(\sum_{i=0}^{7}\sum_{j=0}^{7} a_{ij}^2\right) - DC\_energy \quad (2)$$

where a_{ij} is the pixel data in the 8x8 block.

And, the normalized ratio of AC and DC coefficient energy, AC_DC_ratio is generated by

$$AC\_DC\_ratio = \frac{\log(AC\_energy)}{\log(DC\_energy \times 64)} \quad (3)$$

and is normalized between 0~1.

And, it was proved that the Intra 4x4 macroblocks usually have higher AC/DC ratio while the Intra16x16 macroblocks have lower AC/DC ratio[7]. Thus the intra-coding block size is able to be decided by comparing AC_DC_ratio with the criterion selected to separate different block sizes, and the criterion determines the performance of intra-coding such as visual quality and bitrates. To produce the stable performance considering the target video sequence, contrary to the previous works using empirically given thresholds[7,8,9,10], this paper uses the non-parametric criterion selected by using the second feature mentioned above.

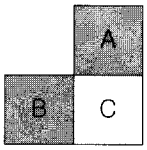

Fig. 3 Neighbor blocks for intra-coding

Usually, in Fig.3, the intra-coding mode of the block C is correlated to the neighbor blocks A and B, and especially, the intra-coding block size of A or B can be the most probable block size for C. Thus, the decision criterion for the intra-coding block size is able to be determined based on the intra-coding block sizes and the smoothness of neighbor blocks. The proposed algorithm decides the intra-coding block size by directly comparing the normalized AC/DC ratio between the current block and neighbor blocks considering the block sizes of neighbor blocks. To ease the description of the proposed algorithm, let $BS(K)$ be the intra-coding block size for the block K, being 4x4 or 16x16, and $NR(K)$ be the normalized AC/DC ratio for the block K. The decision process of the intra-coding block size in the proposed algorithm is as follows:

Step. 1: Select two thresholds T_1 and T_2 having high and low values between 0 and 1, respectively, using the block types and the normalized AC/DC ratios of the neighbor blocks:

if $BS(A)$=4x4 and $BS(B)$=4x4,
then T_1= min($NR(A)$, $NR(B)$) and T_2=0
else if $BS(A)$=16x16 and $BS(B)$=16x16,
then T_1= 1 and T_2=max($NR(A)$, $NR(B)$)
else if $BS(A)$ and $BS(B)$ are different,
then T_1 = $NR(B_{4x4})$ and T_2=NR(B_{16x16})

Step. 2: Decide the most probable block size by comparing the normalized AC/DC ratio of the current block with the two thresholds T_1 and T_2:

if $NR(C)$ is great and equal to T_1,
then $BS(C)$ is selected as 4x4
else if $NR(C)$ is less and equal to T_2,
then $BS(C)$ is selected as 16x16
else all 4x4 and 16x16 are considered as $BS(C)$

Based on the above fast block size decision process, Fig. 4 shows the whole intra prediction algorithm proposed in this paper.

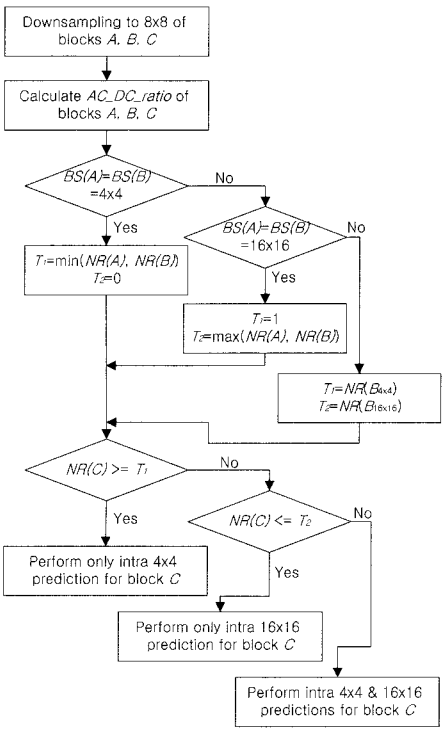

Fig.4 Intra prediction algorithm based on the proposed fast block size algorithm

IV. EXPERIMENTAL RESULTS

For the performance evaluation of the proposed algorithm, the proposed algorithm was implemented into JM 14.2, which is the H.264/AVC reference software[11]. And, we tested the proposed algorithm using four QCIF video sequences(Akiyo, Carphone, Football, Foreman) on the IBM-compatible PC equipped with Intel Pentium-4 2.8GHz and 1GB RAM. The test conditions are summarized in Table 3.

In this experiment, the proposed algorithm was

compared with JM 14.2 and the comparison results are shown in Table 4. In this table, a positive number means increasing and a negative number means decreasing.

Table 3 Test conditions

Video seq. type	Akiyo, Carphone, Football, Foreman
Frame size	QCIF
Frame structure	All I frames
Number of frames	100
RD optimization	Enabled
Entropy coding	CABAC
QP	28, 32, 40

Table 4 shows the comparison results when QP changes to 28, 32 and 40, and it is seen that the proposed algorithm can reduce the computation complexity considerably with a negligible loss in PSNR and bitrates. The amount of change in PSNR and bitrates is extremely low, indicating that the results of the proposed algorithm is very close to the intra prediction based on the full search method in JM 14.2. Also, the values are likely to keep at the similar level regardless video sequence types. The time saving for the entire encoding process is from 18.24% to 28.52%, and if a fast prediction mode decision method for each block size might be integrated to the proposed algorithm, the time saving would be greatly increased.

Table 4 Comparison results between the proposed algorithm and JM 14.2

QP	Video Sequence	ΔTime (%)	ΔPSNR (dB)	ΔBits (%)
28	Akiyo	23.52	-0.01	1.05
	Carphone	18.24	0.0	0.56
	Football	23.12	-0.02	1.45
	Foreman	20.85	0.0	0.32
32	Akiyo	24.76	-0.01	1.63
	Carphone	19.68	0.0	0.68
	Football	25.27	-0.03	2.14
	Foreman	22.71	-0.01	1.16
40	Akiyo	27.38	-0.03	2.26
	Carphone	23.41	-0.01	1.28
	Football	28.52	-0.05	2.87
	Foreman	24.93	-0.02	1.83

Fig. 5 and 6 show the R-D(Rate-Distortion) curves of Carphone and Foreman, respectively. And, Fig. 7 shows one of result frames in Carphone video sequence, indicating that there is almost no difference in the subjective visual quality. From Fig. 5~7, it can be observed that the performance of the proposed algorithm is similar to that of JM 14.2 with the full-search-based intra prediction.

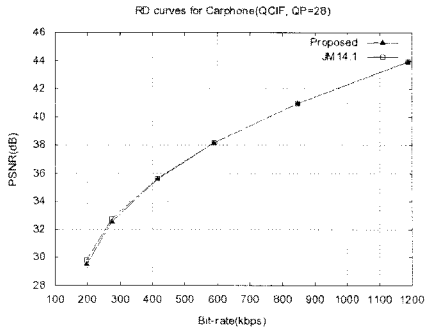

Fig. 5 RD curves of Carphone(QCIF, QP=28)

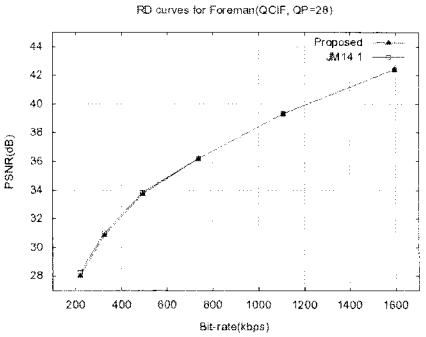

Fig. 6 RD curves of Foreman(QCIF, QP=28)

Fig. 7 Comparison of subjective visual quality in Carphone video sequence

IV. CONCLUSIONS

This paper proposed and evaluated a fast block size decision algorithm for the intra prediction in H.264/AVC. The proposed algorithm decides the best probable block size for the intra prediction by using the relation between the intra-coding block size and the smoothness of a block and the correlation between neighbor blocks in the intra-coding. Also, in the proposed algorithm, the use of non-parametric thresholds in the block size decision excludes the possibility of the dependency of intra coding performance on types of video sequences. The experimental results show that the proposed algorithm is able to achieve a considerable processing time saving in the intra prediction with a negligible loss in

PSNR and bitrates. In future works, we will research the integration of the block size decision algorithm and intra prediction mode decision methods for each block size, which is based on the synthetic consideration of various features observed on the intra coding, to reduce greatly the computation complexity of the intra prediction in H.264/AVC.

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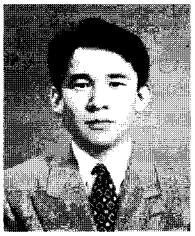

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