Enhanced Intra Mode Bit Skip Algorithm for H.264/AVC

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Abstract **—In this paper, we propose an intra mode bit skip algorithm for H.264 intra 4×4 mode to reduce the mode representation burden. The proposed algorithm enhances the "adaptive intra mode bit skip (AIMBS)" in literature by considering the bit skip for more modes rather than only DC mode. In this work, the correlation between vertical and horizontal differences of reference pixels and encoded modes are investigated. The mode skip of vertical and horizontal prediction modes is integrated with AIMBS. The simulation results show that the proposed mechanism can achieve better coding efficiency than AIMBS.**

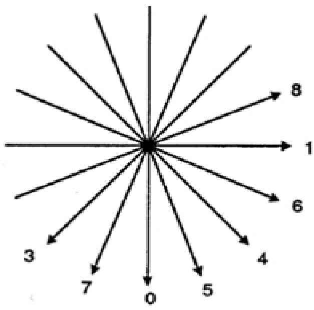
I. INTRODUCTION

H.264/AVC [1] provides two prediction methods to achieve high coding efficiency: the intra prediction to remove spatial redundancy and the inter prediction to remove temporal redundancy. In general, the coding efficiency of inter coding is better than intra coding. However, intra coding is still vital for specific encoding conditions, such as first-frame or scene change frame encoding, random access for playback, error recovery in transmission, and all intra-frame coding for surveillance video. In H.264, the encoder offers 9 prediction modes for every 4×4 luma block. Figure 1(a) shows the current and reference pixels for a 4×4 block, and Fig. 1(b) shows the nine prediction directions. The best prediction mode is determined by comparing the rate-distortion (RD) cost between current and prediction values of each mode in the conventional H.264 intra coding. The prediction values are calculated from reference pixels. Additional information is required to be sent for decoding. For each intra 4×4 luma block, either 1 or 4 bits are required for indicating intra mode in the encoded bit stream for successfully decoding. Therefore, 16-64 bits are required to represent intra mode bits for each intra 4×4 macroblock (MB). It takes more than 10% total bit usage for prediction mode representation in an intra-coded picture [2]. If we can determine the mode by only using the reference pixels without considering the current block, the information for signaling the encoded mode can be skipped.

To reduce the mode bit, an adaptive intra mode bit skip (AIMBS) algorithm was proposed [3], [4]. If all reference pixels of current block are quite similar, all modes result in similar prediction values. In this case, the DC mode can be selected as the prediction mode without significant distortion. Only DC mode is used for prediction so that the bit for signaling the prediction mode can be skipped. And the mode decision for 9 modes is not required. The coding efficiency is improved and the encoding complexity is reduced. But this algorithm can be improved by considering the bit skip for more modes. In this work, we propose an enhanced intra mode bit skip (EIMBS) algorithm to improve the RD performance of AIMBS. The correlation between encoded modes and differences of reference pixels in vertical and horizontal directions are utilized. And the mode skip of vertical and horizontal modes is achieved.

M	A	B	C	D	E	F	G	H
I	a	b	c	d				
J	e	f	g	h				
K	i	j	k	l				
L	m	n	o	p				

(a) Boundary reference pixels (A, B, …, L, M) and current pixels (a, b, …, o, p).



(b) Nine directional prediction modes (2: DC).
Fig. 1 Intra 4×4 prediction.

The rest of this paper is organized as follows. In section II, we briefly introduce AIMBS. Section III presents the proposed EIMBS algorithm. Simulation results are shown in section IV and conclusions are drawn in section V.

II. REVIEW AND ANALYSIS OF ADAPTIVE INTRA MODE BIT SKIP (AIMBS)

A. *Review of AIMBS*

We first introduce the algorithm of AIMBS in this section. Referring to Fig. 1, if all reference pixels of current 4×4 block are quite similar, the prediction values of nine directional prediction modes would be similar, so it is not needed to use nine directional prediction modes in this situation, i.e., only one DC mode is sufficient.

In AIMBS, a parameter σ_p which is the variance of pixels A, B, C, D, I, J, K, and L is used to represent the similarity of reference pixels. If σ_p is smaller than a predefined threshold Th, the current block will be encoded as DC mode directly. Hence no RD cost calculation is required. The threshold *Th* is a quantization step size dependent value, and it is defined as (1).

$$Th = \left\lfloor \frac{Qstep^2 + 8}{16} \right\rfloor \tag{1}$$

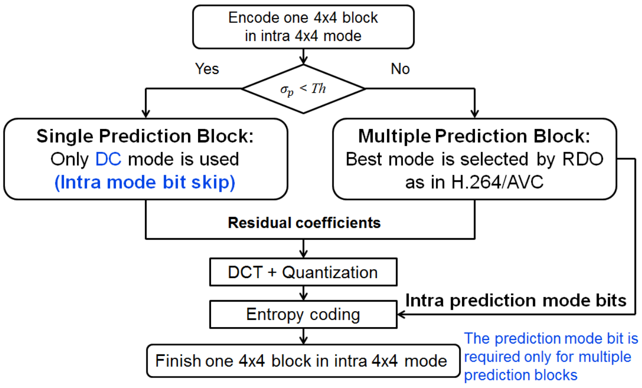


Fig. 2 Flowchart of AIMBS.

Prediction Mode Number	H.264	Proposed Method	
		Single Prediction	Multiple Prediction
0	Vertical	-	Vertical
1	Horizontal	-	Horizontal
2	**DC**	-	Diagonal Down Left
3	Diagonal Down Left	-	Diagonal Down Right
4	Diagonal Down Right	-	Vertical Right
5	Vertical Right	-	Horizontal Down
6	Horizontal Down	-	Vertical Left
7	Vertical Left	-	Horizontal Up
8	Horizontal Up	-	**DC**

Fig. 3 Mode number of multiple prediction block.

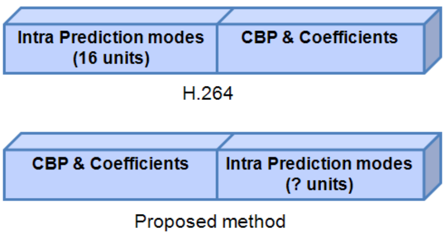


Fig. 4 Bit stream format modification for intra 4×4 prediction.

The flowchart of AIMBS is shown in Fig. 2. The prediction block is classified into two types: single prediction block and multiple prediction block. If σ_p is smaller than *Th*, the current block will be regarded as single prediction block and will be encoded with DC mode. Otherwise, the current block will be regarded as multiple prediction block, and nine intra 4×4 directional predictions are tested. For multiple prediction block, the prediction mode number is reordered as Fig. 3. The reason for this arrangement is that the ratio of DC mode is significantly reduced in multiple prediction blocks. In AIMBS, mode representation bits are required only for the multiple prediction block. Thus, the bits for an intra 4×4 prediction mode are not fixed. In this case, the decoder can not distinguish the intra prediction mode bits and CBP & Coefficients bits. In order to solve this problem, the format of bit stream is modified as Fig. 4.

B. Analysis of AIMBS

AIMBS indeed improves the RD performance while achieving 33%-68% time saving. However, only DC mode is considered in AIMBS, and the accuracy of DC mode is insufficient. Figure 5 shows the mode distribution of original H.264 and AIMBS. We can observe that a lot of blocks that are not DC mode in original encoder are selected as DC mode. Vertical and horizontal modes are the dominant modes in addition to DC mode. Many of these two modes are encoded as DC mode in AIMBS. In this work, we take vertical and horizontal modes into account for bit skip to further improve the coding efficiency of AIMBS.

H.264		AIMBS	
		Single Prediction	Multiple Prediction
Vertical	30.18 %	DC Skip (46.58 %)	14.47 %
Horizontal	18.09 %		11.49 %
DC	**25.37 %**		**6.57 %**
Diagonal Down Left	3.69 %		2.35 %
Diagonal Down Right	3.85 %		2.86 %
Vertical Right	5.76 %		5.09 %
Horizontal Down	3.81 %		3.03 %
Vertical Left	6.10 %		5.00 %
Horizontal Up	3.15 %		2.58 %

(a) Akiyo 50 frames at QP = 22.

H.264		AIMBS	
		Single Prediction	Multiple Prediction
Vertical	16.12 %	DC Skip (82.65 %)	4.15 %
Horizontal	9.28 %		2.04 %
DC	**62.83 %**		**4.74 %**
Diagonal Down Left	2.23 %		0.70 %
Diagonal Down Right	1.21 %		0.70 %
Vertical Right	2.45 %		1.73 %
Horizontal Down	1.43 %		0.98 %
Vertical Left	3.16 %		1.63 %
Horizontal Up	1.28 %		0.69 %

(b) Akiyo 50 frames at QP = 37.

Fig. 5 Mode distribution of H.264 and AIMBS.

III. ENHANCED INTRA MODE BIT SKIP (EIMBS)

A. Statistics Observations

Figure 6 shows the prediction direction of intra 4×4 mode in a part of Foreman sequence. We can find that the prediction directions of neighboring blocks have a high probability to be the same. To observe the correlation between the best mode and reference pixels differences in horizontal and vertical directions, we define two groups of parameters. In this work, the reference pixel is extended with 1 pixel in horizontal and vertical directions as shown in Fig. 7.

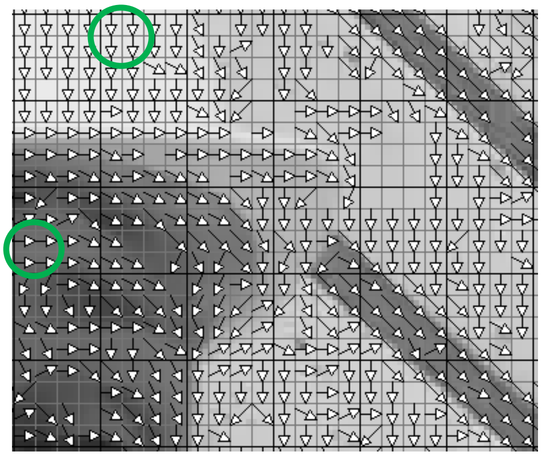


Fig. 6 Prediction direction in a part of "Foreman" sequence with CIF resolution.

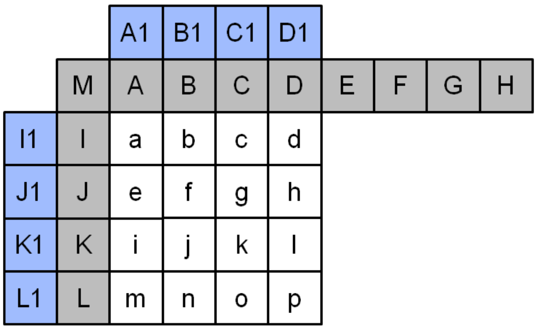


Fig. 7 Reference pixel extension.

In vertical direction, the vertical differences (**VDs**) are defined as follows.

$$D_{Ver}^{up} = [(A1-A)^2 + (B1-B)^2 + (C1-C)^2 + (D1-D)^2]/4$$
$$D_{Ver}^{left1} = [(I1-J1)^2 + (J1-K1)^2 + (K1-L1)^2 + (L1-I1)^2]/4$$
$$D_{Ver}^{left2} = [(I-J)^2 + (J-K)^2 + (K-L)^2 + (L-I)^2]/4$$

In horizontal direction, the horizontal differences (**HDs**) are defined as follows.

$$D_{Hor}^{left} = [(I1-I)^2 + (J1-J)^2 + (K1-K)^2 + (L1-L)^2]/4$$
$$D_{Hor}^{up1} = [(A1-B1)^2 + (B1-C1)^2 + (C1-D1)^2 + (D1-A1)^2]/4$$
$$D_{Hor}^{up2} = [(A-B)^2 + (B-C)^2 + (C-D)^2 + (D-A)^2]/4$$
$$D_{Hor}^{up3} = [(A-B)^2 + (B-C)^2 + \ldots + (G-H)^2 + (H-A)^2]/8$$

By observing the distribution of these parameters, the trends of intra 4×4 mode selection in H.264 can be summarized as follows.

a) Vertical differences (**VDs**) of reference pixels have high probabilities to be zero when the best mode is vertical mode.

b) Horizontal differences (**HDs**) of reference pixels have high probabilities to be zero when the best mode is horizontal mode.

c) All differences tend to be 0 for DC mode.

d) When the 4×4 block is located at the frame boundary, the best prediction mode is restricted to some specific modes because of the lack of some reference pixels. If the block is located at the upper frame boundary and the differences of I, J, K, and L ($D_{Ver}^{left2} = 0$) is zero, the best prediction mode is DC mode. It is similar for left boundary, if A = B = C = D ($D_{Hor}^{up2} = 0$), the best mode is also DC mode. These two cases are called frame boundary (**FB**) condition in this work.

B. Enhanced Intra Mode Bit Skip Algorithm (EIMBS)

Based on the observations in previous subsection, we integrate the mode bit skip of vertical and horizontal modes with AIMBS to improve its RD performance. The proposed algorithm is slight different for high QP and low QP. In this work, QP higher than 28 is treated as high QP, and high QP rule is applied. And low QP rule is used for QP lower than 28. This demarcation for QP is obtained by experiments to achieve good RD performance.

Figure 8 is the flowchart of the proposed EIMBS algorithm for low QP. If QP is smaller than or equal to 28, we use low QP rule for prediction. At low QP rule, if **VDs** are zero and **HDs** are greater than zero, the single vertical mode is selected as the best mode for encoding and the mode bit is skipped. On the contrary, if **HDs** are zero and **VDs** are greater than zero, the horizontal mode is selected as the best mode and the mode bit is skipped, too. If all differences are zero, or the **FB** condition is satisfied, or the variance σ_p is smaller than threshold Th, DC mode is selected and the mode bit is skipped. Other details are the same as AIMBS.

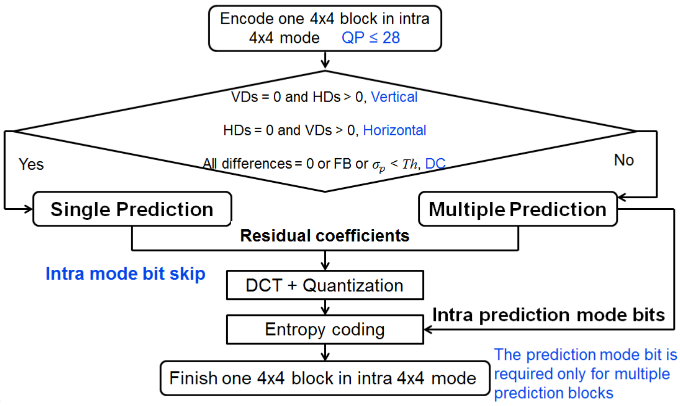


Fig. 8 Low QP rule of EIMBS.

Figure 9 shows the flowchart of the proposed EIMBS algorithm for high QP. When the QP is larger than 28, we use high QP rule for prediction. There are more blocks will be selected as single prediction block in original AIMBS because of the larger threshold for high QP. Therefore in high QP case, we focus on enhancing the accuracy of original single mode prediction. If σ_p is smaller than Th, and **VDs** are zero, and D_{Hor}^{left} is larger than zero, the vertical mode is selected as best mode and the mode bit is skipped. Similarly, if σ_p is less than Th, and **HDs** are zero, and D_{Ver}^{up} is larger than zero, the horizontal mode is selected. Finally, if the block satisfies the **FB** condition or σ_p is smaller than Th, DC mode skip is applied.

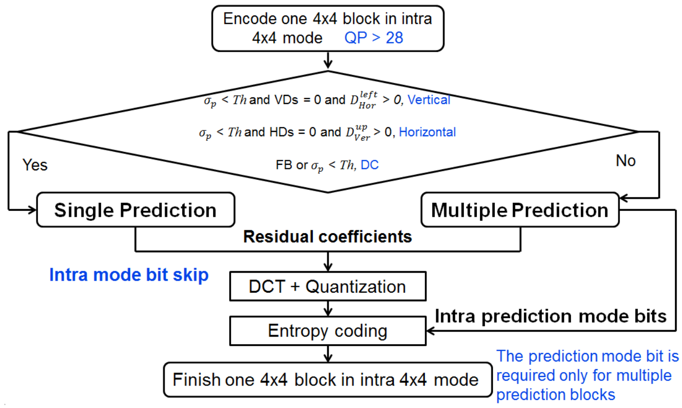


Fig. 9 High QP rule of EIMBS.

IV. Simulation Results

The proposed EIMBS algorithm is implemented on H.264/AVC reference software JM 11.0 [5]. The simulation conditions are listed in Table I. All sequences are encoded with all intra frames. And the RD performance is evaluated in terms of BD rate and BD PSNR [6].

Table II shows simulation results for CIF sequences and Table III shows simulation results for 1080p sequences. On average, AIMBS achieves 1.86% BD rate reduction and EIMBS achieves 2.11% BD rate reduction for CIF video compared with original JM encoder. For 1080p sequences, average bitrate reduction of AIMBS is 2.85% and EIMBS is 3.56%. The performance of the proposed EIMBS is obviously better than AIMBS in most cases.

TABLE I
Simulation Conditions

JMKTA 1.9r1 (JM 11)		
Resolution	CIF	1080P
Sequence	Akiyo, Foreman, Mobile, Paris	Pedestrian area, Rush hour, Tractor, Station2
Frame Rate	30.0	60.0
Sequence type	All frames are Intra coded	
Encoding mode	All Intra4x4 and 16x16 are used	
Profile	Baseline (CAVLC)	
Adaptive Rounding	Disabled	
RD-Optimization	Enabled	
Intra8x8	Disabled	
QP	22, 27, 32, 37	

V. Conclusion

The proposed algorithm utilizes the pixel correlations to skip the mode bits of vertical and horizontal modes to enhance AIMBS. On average, the proposed algorithm can improve 0.017dB in BD PSNR and 0.25% bitrate reduction in BD rate at CIF sequence, 0.029 dB and 0.73% at 1080P compared with AIMBS. The average encoding time is further reduced by 0.8% compared with AIMBS. If we can find pixel characteristics of other modes not only vertical and horizontal modes, the coding efficiency and encoding time can be improved more.

TABLE II
Performance of CIF Sequences

Sequence CIF	QP	H.264		AIMBS		EIMBS	
		Bitrate (Kbps)	PSNR (dB)	BD rate (%)	BD PSNR(dB)	BD rate (%)	BD PSNR(dB)
Akiyo	22	2306.583	43.956	-2.94	0.201	-3.67	0.254
	27	1470.638	40.980				
	32	938.179	37.810				
	37	614.713	34.779				
Foreman	22	4450.85	41.718	-2.97	0.181	-3.05	0.185
	27	2679.639	38.010				
	32	1566.996	34.700				
	37	915.094	31.777				
Mobile	22	10755.641	40.926	-0.52	0.057	-0.52	0.057
	27	7609.111	36.268				
	32	5140.663	31.835				
	37	3298.457	27.870				
Paris	22	6656.032	41.581	-1.02	0.092	-1.18	0.106
	27	4532.855	37.448				
	32	2971.451	33.503				
	37	1892.419	29.890				
Average				-1.86	0.133	**-2.11**	**0.151**

TABLE III
Performance of 1080p Sequences

Sequence 1080P	QP	H.264		AIMBS		EIMBS	
		Bitrate (Kbps)	PSNR (dB)	BD rate (%)	BD PSNR(dB)	BD rate (%)	BD PSNR(dB)
Pedestrian area	22	60951.764	43.141	-3.17	0.122	-4.29	0.161
	27	32224.858	41.197				
	32	19425.926	39.142				
	37	12359.078	36.975				
Rush hour	22	49163.596	43.169	-2.17	0.069	-2.77	0.086
	27	24966.796	41.822				
	32	15456.307	40.183				
	37	10207.603	38.229				
Tractor	22	129909.928	42.816	-1.46	0.081	-2.04	0.112
	27	75755.408	39.727				
	32	45115.776	36.726				
	37	28383.188	33.902				
Station2	22	79598.688	42.476	-4.60	0.197	-5.13	0.218
	27	43237.016	40.034				
	32	25178.132	37.629				
	37	15057.350	35.234				
Average				-2.85	0.117	**-3.56**	**0.144**

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