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Context-adaptive coded block pattern coding for H.264/AVC

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Abstract: For coding of quantized transform coefficients, a coded block pattern (CBP) is a key syntax element to represent the existence of coefficients in a macroblock efficiently. In H.264/AVC, the CBP is coded by using a fixed variable length coding table, called Exp-Golomb codes. However, since the CBP is highly affected by the change of quantization parameter (QP), in this paper, we show the CBP distributions according to the change of QP and propose an context-adaptive CBP coding method. The proposed scheme selects the coding table adaptively based on the context of neighbors' CBP. Experimental results show that the proposed scheme reduces average 1.15% in total bit rate and 12.54% in CBP bit rate compared to the anchor, H.264/AVC.

Keywords: H.264/AVC, CBP, entropy coding

Classification: Electron devices, circuits, and systems

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1 Introduction

In the latest video coding standard, H.264/AVC, syntax elements are efficiently coded with two variable length coding techniques: one is the context-adaptive variable length coding (CAVLC) and the other is the exponential golomb coding (Exp-Golomb) [1]. Due to these efficient entropy coding techniques, H.264/AVC provides better compression performance compared to previous standards such as MPEG-2/4 and H.263 [2, 3, 4].

For syntax elements of quantized transform coefficients, CAVLC compresses them efficiently by introducing the context-adaptive coding concept to support the change of quantization parameter (QP) [5], but for the rest of syntax elements, Exp-Golomb code provides a fixed coding table without considering the variation of QP. However, the syntax elements are affected by the change of QP because QP controls the number of non-zero coefficients in a block. Especially, a coded block pattern (CBP) highly depends on the change of QP because it represents whether transform coefficients exist in a 8×8 block or not.

Therefore, in this paper, we show the necessity of the adaptive coding technique for CBP coding experimentally, then propose the context-adaptive CBP coding scheme to support the variation of QP efficiently. Compared to the conventional CBP coding method, H.264/AVC, experimental results show that the proposed method reduces total bit rate by up to 1.63% and CBP bit rate 22.47% in BDRATE. The rest of this paper is organized as follows. Section 2 reviews the definition of CBP briefly, then shows the change of CBP distribution according to QP. The proposed CBP coding method is presented in Section 3. Simulation results are reported in Section 4, and Section 5 concludes this paper.

2 Distributions of CBP and QP

The CBP is a syntax element specified in the macroblock layer and indicates which of the four 8x8 luma blocks and associated chroma blocks in a macroblock may contain non-zero transform coefficients. A CBP consists of six bits $b_5b_4b_3b_2b_1b_0$, where $b_3b_2b_1b_0$ specifies four luma blocks (CBPLuma) and b_5b_4 specifies associated chroma blocks (CBPChroma). In the CBPChroma case, two bits b_5b_4 are not just allocated for each chroma block but classified into three groups as following:

- CBPChroma=00(0), if all chroma coefficients are equal to 0.
- CBPChroma=01(1), if one or more chroma DC coefficients shall be non-zero and all chroma AC coefficients are equal to 0.
- CBPChroma=10(2), if zero or more chroma DC coefficients are non-zero and one or more AC coefficients shall be non-zero.

For this reason, the total number of CBP type is $16 \times 3 = 48$, the number of combinations of 4 luma blocks and 3 chroma patterns.

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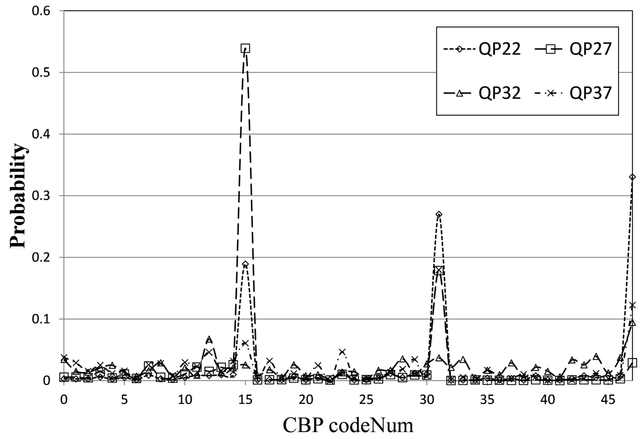
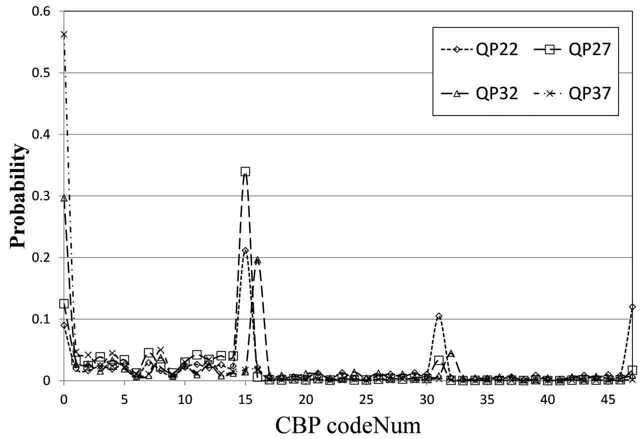


(a) for Intra block



(b) for Inter block

Fig. 1. The CBP distributions according to the change of QP

Now, we investigate the effects of QPs on the CBP distributions. Figure 1 shows the CBP distributions according to the variations of QPs for intra and inter cases. In Fig. 1 (a) for intra case, the occurrence probabilities of QP22 at 15^{th}, 31^{st}, and 47^{th} positions are higher than other positions. At these positions, all of the CBPLuma's bit values ($b_3b_2b_1b_0$) have 1s, which means that at least one transform coefficient exists in all 8×8 blocks. However, the probabilities of QP37 at 15^{th}, 31^{st}, and 47^{th} are relatively reduced compared to the QP22 case, but those at the positions 12^{th}, 17^{th}, 21^{st}, and 23^{rd} are slightly increased. At those positions, the transform coefficients of luma components are partially existed (CBPLuma $\neq 0$). These results are sufficiently expected, because the QP controls the number of transform coefficients in a block.

For the inter case, the CBP distributions slightly differ from the intra case. From Fig. 1 (b), the probability of CBP for inter blocks is rather skewed into at the position of zero code number. This is caused by the amount of transform coefficients to transmit. Due to the effectiveness of temporal redundancy reduction tools, for the inter case, the portion of the block containing

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non-zero transform coefficients is lower than the intra case. In Fig. 1 (b), the occurrence probabilities of QP22 at 0^{th}, 15^{th}, 31^{st}, 47^{th} are relatively higher than other positions. On the other hand, the occurrence probabilities of QP37 at 0^{th}, 15^{th}, 31^{st}, 47^{th} are decreased and the probability at 0^{th} is extremely increased.

From the preliminary experiments, we conclude that the even CBP should be adaptively coded with considering the variation of QPs. Based on this observation, we propose the context-adaptive CBP coding scheme in the next section.

3 Proposed CBP coding method

In section 2, we discussed that the CBP distributions for intra and inter mode are changed according to the variation of QPs. Since the CBP is affected by QPs, if we assume that all QPs in a slice have equal values, the CBP of the current block is highly correlated with the CBPs of neighbor blocks. In order to reflect the changes of QPs efficiently, we set two coding parameters, avgCBPLuma and avgCBPChroma. The avgCBPLuma is defined by averaging the count of 8×8 luma transform coefficients' existence in the neighbor macroblock A and B, and the avgCBPChroma is defined by averaging the CBPChroma values of the neighbor macroblock A and B.

Let us explain the calculation of avgCBPLuma and avgCBPChroma with an example in Fig. 2. If neighbor macroblock A has 2 non-zero transform coefficient blocks and B has 4 non-zero blocks as in Fig. 2 (a), then avgCBPLuma is calculated as 3. For the CBPChroma case as in Fig. 2 (b), if the neighbor macroblock A has the CBPChroma value 2 (one of two DC components has 1 value and two AC components have 0 values) and B has CBPChroma $= 0$ (All DC and AC components are 0s), then the avgCBPChroma is calculated as 1. Based on these two parameters, we set four contexts as follows.

- Context=0, if avgCBPLuma ≥ 2 and avgCBPChroma ≥ 1.
- Context=1, if avgCBPLuma ≥ 2 and avgCBPChroma < 1.

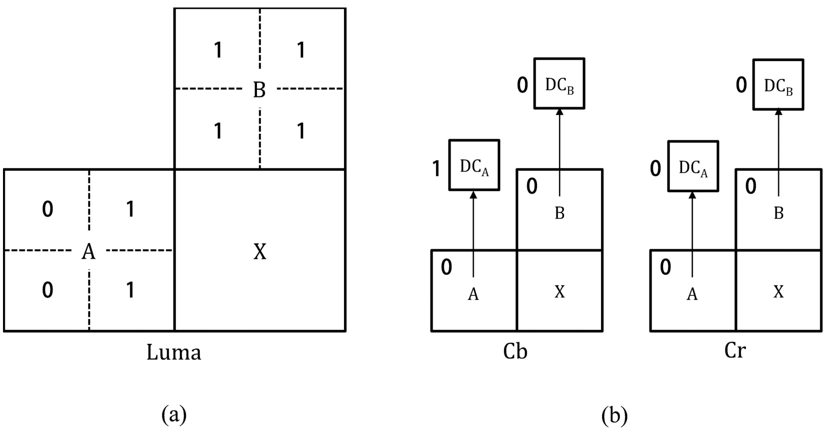

Fig. 2. An example of the calculation for avgCBPLuma and avgCBPChroma

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- Context=2, if avgCBPLuma < 2 and avgCBPChroma ≥ 1.
- Context=3, if avgCBPLuma < 2 and avgCBPChroma < 1.

For the context 0 and 1 cases, we set both avgCBPLuma to have a high value in order to reflect the high and middle rates conditions efficiently and set the avgCBPChroma to have low and high, respectively. On the other hand, for the context 2 and 3 cases, we set the avgCBPLuma as a low value to cover the middle and low rates conditions.

4 Simulation results

To evaluate the coding performance of the proposed scheme, we implemented the proposed scheme in JM11.0KTA2.7 software, which is most recently updated [6]. In the simulations, the baseline profile and IPPP structure are used under VCEG common test conditions [7] except 1 reference frame. The coding performances of the previous work and the proposed scheme are evaluated in terms of BDRATE [8]. All comparison is made against the KTA 2.7 software as an anchor. Note that the tables for four contexts were estimated in advance (offline-trained) and generated by Huffman codes for training sequences which are not included in test sequences.

Table I shows the experimental results between the H.264/AVC and the proposed method for CBP syntax elements. The overall average coding gain is approximately 1.15% reduced in BDRATE (noted BDRATE_{tot} in Table I) and the average CBP coding gain is 12.54% in BDRATE (noted BDRATE_{cbp}) compared to the KTA 2.7 software as an anchor. In Table I, the average gain of the proposed method for each resolution increases according to the size of resolution. The average gain of HD (1280×720) sequences is 1.51% compared to H.264/AVC and that of QCIF (176×144) sequences is 0.91% in BDRATE. This relatively increased gain of higher resolution sequences results from the increase of the number of macroblock in higher resolution. In the sense of BDRATE_{cbp}, especially, for City sequence containing complex textures and panning camera motion, the proposed method provides a higher

Table I. Experimental results for VCEG test sequences

QP: 22, 27, 32, 37, ref_num=1			Proposed vs. Anchor		
SIZE	FrameSkip	Sequence	BDRATE_{tot}[%]	BDRATE_{cbp}[%]	DCPX[%]
QCIF	1	Container	−0.786	−3.736	0.716
	1	Foreman	−1.069	−15.810	0.796
	1	Silent Voice	−0.868	−6.521	0.911
CIF	1	Paris	−0.971	−3.165	0.807
	0	Foreman	−1.306	−14.634	0.747
	0	Mobile	−0.844	−9.726	0.836
	0	Tempete	−1.014	−12.312	0.916
720P	0	ShuttleStart	−1.591	−16.514	1.086
	0	Night	−1.420	−12.463	1.096
	0	Crew	−1.566	−17.500	1.119
	0	Bigships	−1.354	−15.583	1.236
	0	City	−1.634	−22.472	1.344
Average of QCIF			−0.908	−8.689	0.808
Average of CIF			−1.034	−9.959	0.827
Average of 720P			−1.513	−16.906	1.176
Average of Overall			−1.152	−12.536	0.968

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compression gain, but for Container, Silent Voice, and Paris sequences (CSP sequences) having homogeneous textures and the static camera motion, the proposed method shows a relatively smaller gain. The result is affected by the change of syntax elements in a bitstream. Due to the large portion of homogeneous region in CSP sequences, the portion of skip mode and/or zero coefficient blocks in those sequences are larger than in City sequence, and thus BDRATE$_{cbp}$ is rather smeared but highly effective to the overall gain.

The complexity of the proposed method compared to the anchor is approximately 0.97% increased in terms of DCPX (Delta ComPleXity percentage) as Eq. (1). This increment value is sufficiently acceptable when we consider the absolute computational complexity of video coding.

$$DCPX(\%) = \frac{proposed\_complexity - anchor\_complexity}{anchor\_complexity} \times 100(\%) \qquad (1)$$

5 Conclusions

This paper presents a context-adaptive coded block pattern coding scheme for H.264/AVC. In contrast to the conventional method which supports a fixed coding table, the proposed scheme provides four adaptive coding tables to adapt the variation of neighbors' CBPs and QPs. Therefore, the proposed method can be additionally implemented on the structure of the conventional method without major modifications. Experimental results also show that the proposed scheme reduces the overall coding performance by up to 1.63% and the CBP coding performance by up to 22.47% in BDRATE without the high increase of the computational complexity compared to the anchor, H.264/AVC.

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