

LETTER

Fast Intra Mode Decision for Screen Contents Coding in HEVC

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SUMMARY In this letter, fast intra mode decision algorithms for HEVC Screen Contents Coding (SCC) are proposed. HEVC SCC has been developed to efficiently code mixed contents consisting of natural video, graphics, and texts. Comparing to HEVC version 1, the SCC encoding complexity significantly increases due to the newly added intra block copy mode. To reduce the heavy encoding complexity, the evaluation orders of multiple intra modes are rearranged and several early termination schemes based on intermediate coding information are developed. Based on our evaluation, it is found that the proposed method can achieve encoding time reduction of 13~30% with marginal coding gain or loss, compared with HEVC SCC test model 2.0 in all intra (AI) case.

key words: HEVC, intra coding, screen contents coding, fast mode decision

1. Introduction

In 2013, High Efficiency Video Coding (HEVC) version 1 was standardized by the Joint Collaborative Team on Video Coding (JCT-VC) of ISO/IEC MPEG and ITU-T VCEG. HEVC version 1 was designed to support 8-bit bit depth and 4:2:0 color sampling. In addition, HEVC version 2 with Range Extensions (RExt) has been released to support high bit depth and extended color samplings such as 4:2:2 or 4:4:4. Recently, HEVC Screen Contents Coding (SCC) has attracted great attention of many video experts. SCC focuses on coding for mixed contents consisting of natural video, graphics, and texts.

Among the new added coding tools for SCC, intra block copy (IBC) is one of the key techniques that provide significant bitrate savings for mixed videos. IBC is a block matching technique that generates a prediction block from the reconstructed region, region of a current picture, and the corresponding displacement is represented by a block vector (BV) similar to a motion vector (MV) of inter prediction. In common with motion estimation process of inter prediction, BV search process is performed to find the best BV, and the resultant BV is predicted and then transmitted to the decoder. Average bitrate gains of IBC mode are found to be in the range of 2% to 44%. In addition, we found that occurrence probability of IBC mode is in range of 20% to 67% for screen content videos [1], [2]. However, IBC mode

prediction requires significant encoding complexity due to the BV search process [3].

2. Mode Decision Process of SCM Encoder

In HEVC SCC reference model (SCM) encoder, variable prediction units of IBC mode, such as IBC 2N×2N, IBC N×2N, IBC 2N×N, and IBC N×N, are adopted as new intra coding modes. Due to additional mode decision process for the new coding modes, intra coding complexity significantly increases. Figure 1 presents the flowchart of the mode decision process of SCM 2.0 encoder. As shown in the figure, RD costs for additional IBC modes are evaluated after the conventional intra coding modes such as Intra 2N×2N, Intra N×N, and Intra PCM.

To reduce encoder complexity for SCC intra coding, several fast encoding methods [4], [5] have been introduced during the standardization activity. In [4], a fast IBC search method was proposed by using 1-D search for 16×16 CUs and 2-D search for 8×8 CUs while IBC searches for 64×64 and 32×32 CUs are skipped. In [5], early termination schemes of IBC search based on intra mode cost and CU activity for 8×8 CUs were proposed. These two methods were adopted in the SCM reference model. To achieve further reduction of encoding complexity on top of the adopted fast encoding methods in SCM, the rearrangement of evaluation orders for multiple intra prediction modes and several early termination schemes based on the intermediate coding information of an IBC 2N×2N mode are proposed in this letter.

3. Proposed Methods

Three early termination methods of SCC intra coding mode decision to reduce the encoding complexity are proposed.

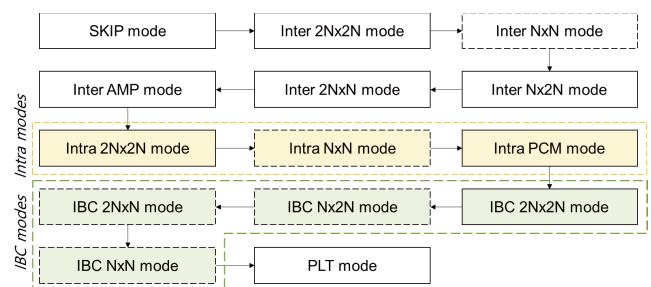


Fig. 1 Coding unit (CU) mode decision process in SCM 2.0.

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All proposed methods were designed to find different trade-offs between the encoding complexity and coding efficiency according to applications.

In the first early termination method ('Method1'), IBC 2Nx2N mode is evaluated and the coded block flag (CBF) is checked whether the remaining intra coding modes can be skipped or not. If the CBF of the IBC 2Nx2N mode is equal to zero, the encoding processes of the remaining intra coding modes (e.g. Intra 2Nx2N, Intra NxN, Intra PCM, IBC 2NxN, IBC Nx2N, and IBC NxN) are skipped. In this letter, a condition, named 'C1' is defined to check whether CBF of IBC 2Nx2N mode is equal to zero or not. The condition is developed to check zero quantized residual energy from IBC prediction, which implies that the prediction accuracy by IBC 2Nx2N mode is sufficiently good. Figure 2 shows examples of residual blocks from inter mode, intra mode, and IBC mode. It can be said that the residual block from the IBC mode is notably similar to that from the inter mode rather than intra mode.

The second early termination method ('Method2') checks 'C1' condition as well as a block vector difference (BVD) of IBC 2Nx2N mode for skipping the mode decision process of the remaining intra coding modes. The condition is to check whether BVD of the IBC 2Nx2N is equal to (0, 0), so called 'C2' condition in this letter. In 'Method2', when both the BVD and the CBF of the IBC 2Nx2N mode are respectively equal to (0, 0) and zero, the remaining intra coding modes are skipped. 'C2' condition is designed to assure that the BV can be perfectly predicted from the neighboring blocks. When 'C1' and 'C2' conditions are satisfied, we can say that IBC 2Nx2N mode is likely to be selected as the best coding mode against the remaining intra coding modes.

Table 1 shows joint probabilities of CBF and BVD when IBC 2Nx2N is chosen as the best mode in SCM 2.0. As shown in table, the probability of zero CBF, $P(CBF_Z)$, is 0.90 that is significant high, compared to that of non-zero CBF, $P(CBF_{NZ})$. It means that 'C1' condition is highly related to the case that no other evaluation processes are necessary. Moreover, Table 1 shows that 'C2' condition can be also meaningful for this purpose. The probability of zero



Fig. 2 Similarity of residual blocks according to prediction modes (a) residual block of Inter 2Nx2N mode (b) residual block of IBC 2Nx2N modes (c) residual block of Intra 2Nx2N mode.

Table 1 Joint probabilities of CBF and BVD, subject to IBC 2Nx2N mode.

	Zero CBF	Non-zero CBF	Total
Zero BVD	0.78	0.04	0.82
Non-zero BVD	0.12	0.06	0.18
Total	0.90	0.10	1.00

BVD, $P(BVD_Z)$, is observed to be 0.82 and the joint probability of zero BVD and zero CBF, $P(BVD_Z \& CBF_Z)$ is 0.78, which is still high.

The third proposed method ('Method3') is designed for the case that 'C1' condition is not satisfied. The additional condition ('C3') is to check whether a current block is coded by IBC 2Nx2N mode or conventional Intra 2Nx2N mode. 'C3' condition can be written by

$$J(IBC_{2N \times 2N}) < J(Intra_{2N \times 2N}),$$

$$\text{where } J(m) = D(m) + \lambda \cdot B(m), \quad (1)$$

where $J(m)$ is the Lagrangian rate-distortion (RD) cost according to mode m . $D(m)$ and $B(m)$ represent the distortion and the total number of bits, respectively.

'C1' condition is used to check whether the CBF is equal to zero. If the CBF is zero, the IBC 2Nx2N mode is selected without RD computation for all the remaining modes. In the case of non-zero CBF, 'C3' condition is used to decide whether the IBC prediction modes or the conventional intra prediction modes are performed. If RD cost of IBC 2Nx2N mode is less than that of Intra 2Nx2N mode, the encoding process of the next conventional intra coding modes (e.g. Intra NxN and Intra PCM) is skipped since it can be thought that the IBC modes can be more effective than the conventional intra modes. Otherwise, the mode decisions of the remaining IBC modes (e.g. IBC Nx2N, IBC 2NxN, IBC NxN) are skipped.

The flowchart of the proposed schemes is shown in Fig. 3. As shown in Fig. 3, IBC 2Nx2N mode is checked before checking the Intra 2Nx2N mode. If the CBF of the IBC 2Nx2N mode is equal to zero, the mode decision processes of the remaining intra coding modes are skipped. As shown in Fig. 3(a), 'Method2' also checks 'C2' condition. If either 'C1' or 'C2' condition is not satisfied, the mode decisions of the remaining intra coding modes are evaluated. In Fig. 3(b), 'Method3' checks 'C3' condition after evaluating Intra 2Nx2N mode.

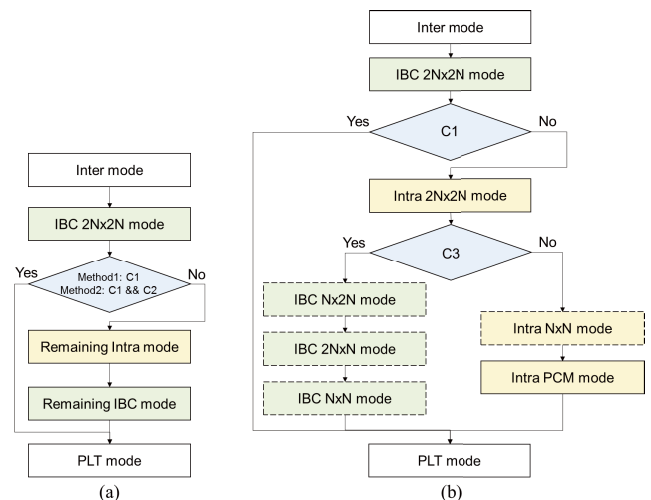


Fig. 3 Mode decision process of three proposed method (a) flowchart of 'Method1' and 'Method2' (b) flowchart of 'Method3'.

4. Performance Evaluation

Three proposed methods were integrated on the HEVC SCC reference software, HM-15.0+RExt-8.0+SCM-2.0 [6] and they were evaluated under the common test conditions used in the HEVC SCC standardization activity [7]. Fast encoding tools [4], [5] in SCM 2.0 encoder were used for all the test cases. The performance of three proposed methods was measured in the BD-rate [8] and relative encoding time ratio against the original SCM 2.0.

BD-rate and encoding time ratio of the three proposed methods are shown in Table 2. ‘TGM’ means that test sequences consist of texture and graphics with motion, and ‘M’ means mixed contents. ‘A’ represents animation sequences and ‘CC’ does camera-captured sequences.

As shown in Table 2, the proposed ‘Method1’ shows the encoding times saving of 19% with the marginal 0.5% BD-rate loss on average. ‘Method2’ shows the encoding time saving of 13% even with 0.2% BD-rate gain on average. Especially, it achieves 2.3% BD-rate gain in text and graphics with motion RGB sequences. ‘Method3’ achieves encoding time saving of 30% with 1.2% BD-rate loss. Among the proposed methods, ‘Method2’ yields the best RD performance in BD rate, and the ‘Method3’ is the best method in terms of the encoding complexity reduction.

Table 2 BD-rate and encoding time ratio for all intra (AI) case.

	Method1			Method2			Method3		
	G/Y	B/U	R/V	G/Y	B/U	R/V	G/Y	B/U	R/V
RGB, TGM, 1080p	-0.2	-1.8	-1.8	-2.3	-2.1	-2.1	-1.1	-1.0	-1.0
RGB, TGM, 720p	0.3	0.2	0.2	-0.3	-0.4	-0.4	1.2	1.0	1.1
RGB, M, 1440p	0.2	0.3	0.1	-0.3	-0.2	-0.3	1.4	1.3	1.2
RGB, M, 1080p	0.0	0.1	0.0	-0.4	-0.4	-0.4	1.0	0.7	0.7
RGB, A, 720p	0.5	0.5	0.5	0.1	0.1	0.1	0.9	0.9	-1.2
RGB, CC, 1080p	0.5	0.2	0.4	0.1	0.0	0.1	0.6	0.4	0.6
YUV, TGM, 1080p	0.3	0.3	0.3	-0.1	-0.1	0.0	1.4	1.1	1.1
YUV, TGM, 720p	1.4	0.8	0.8	0.3	0.1	0.0	2.1	1.3	1.0
YUV, M, 1440p	1.1	0.5	0.5	0.1	-0.1	-0.2	2.2	1.0	0.9
YUV, M, 1080p	0.8	0.7	0.5	0.0	0.0	0.0	1.9	1.3	1.1
YUV, A, 720p	1.4	0.6	0.4	0.3	0.1	0.0	1.9	1.0	0.8
YUV, CC, 1080p	0.9	0.2	0.5	0.2	0.0	0.1	1.1	0.3	0.7
Average	0.5	0.2	0.2	-0.2	-0.3	-0.3	1.2	0.8	0.6
Encoding time[%]	Minimum			73			82		
	Maximum			94			97		
	Average			81			87		

5. Conclusion

This letter proposes three fast intra mode decision methods for screen contents coding based on HEVC. It is reported that the proposed methods have encoding time reductions of about 13~30% on average with $-0.19\sim 1.22\%$ BD-rate change, compared to the HEVC reference encoder for all intra (AI) case. In particular, ‘Method1’ was adopted in the HEVC SCC reference model (SCM) during the standardization activity [9].

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