DECODER SIDE MERGE MODE AND AMVP IN HEVC SCREEN CONTENT CODING

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ABSTRACT

Intra Block Copy (IBC) mode in a screen content coding (SCC) extension in High Efficiency Video Coding (HEVC) provides high coding gain by performing motion estimation (ME) and motion compensation (MC) to find the repetitive patterns within the same frame. Merge mode and Advanced Motion Vector Prediction (AMVP), which are originally used for inter mode, are also applied to the IBC mode. However, there are redundant coding bits when they are applied to IBC. Therefore, we propose decoder-side merge mode and AMVP for IBC in SCC so as to remove the redundancy. Experimental shows that the proposed method can achieve up to 0.25% Bjontegaard delta bitrate (BD-rate) reduction compared to the conventional SCC with negligible impact to encoding and decoding complexity.

Index Terms— AMVP, HEVC, Intra Block Copy, Merge Mode, Screen Content Coding

1. INTRODUCTION

Screen content coding (SCC) [1] has been introduced as an extension to High Efficiency Video Coding (HEVC) [2] for encoding the screen content videos captured or generated by software applications such as remote desktop and video conferencing with the sharing of slideshows.

Screen content is the video content, such as texts and graphical user interface captured at the computer screen. It can be the mixed content from camera-captured content and screen content. While camera-captured content has already been efficiently encoded by HEVC, screen content cannot be encoded by HEVC efficiently due to its distinctive characteristics from the camera-captured content. There are several characteristics of screen content including complex structure, sharp edges sometimes with high contrast and repetitive patterns. HEVC cannot handle these kinds of screen contents well. Therefore, palette (PLT) mode [3-4] has been introduced to encode the blocks with complex structure and sharp edges. Intra block copy (IBC) mode [5-7] has been used for encoding repetitive patterns within the same frame.

The IBC mode adopts the HEVC motion vector prediction mechanism [8-9], called AMVP, (Advanced Motion Vector Prediction) for inter mode as well as the merge/skip mode [10]. It is noted that the skip mode can be treated as a special case of the merge mode in which the predicted blocks do not contain any residual errors. Five motion vector predictors (MVPs) and two MVPs are derived for merge mode and AMVP, respectively, based on the spatial and temporal neighbor motion vectors (MVs) around the coding block [11]. Zero MVs are inserted as MVPs if the MVPs derived are fewer than five and two for merge mode and AMVP respectively. However, as IBC is to find repetitive patterns within the same frame, zero MV is not a reasonable MVP in IBC. This is because zero MVs in IBC is an invalid MV in the sense that it points to the current block within the same frame which is not yet reconstructed at both encoder and decoder sides. Bit redundancy is appeared at the conventional motion vector prediction mechanism. Thus, in this paper, we propose the decoder-side merge mode and the AMVP to overcome this problem. In the remaining sections, we firstly describe the conventional merge mode and AMVP for inter mode in HEVC as well as IBC in SCC in Section 2. Next, our novel decoder-side AMVP and merge mode are proposed with analyses in Section 3. Finally, experimental results are shown in Section 4 with conclusions drawn in Section 5.

2. BACKGROUND

For AMVP in HEVC [11], two MVPs are used to form the candidate list for the prediction of inter mode. Two spatial MVPs are chosen. One from left $\{A_0, A_1\}$ prediction units (PU) and one from top $\{B_0, B_1, B_2\}$ PUs based on the availability and pre-defined order, as depicted in Fig. 1. If they are duplicated, one would be removed. If the number of MVPs is smaller than two, one temporal MVP from the co-located right bottom (T_B) or the centered co-located (T_C) PU based on the availability and pre-defined order is added to the candidate list. If the number of MVPs is still smaller than two, zero MVs are used to fill in the candidate list to make it two MVPs. Fig. 2 shows the AMVP candidate list reconstruction process. During motion estimation (ME) [12-14] for the current PU, the one which gives the smaller bits for motion vector differences (MVDs) would be selected as the best MVP for that current PU. And there would be a bit coded for the PU to indicate which MVP is used.

For merge mode in HEVC [11], four spatial MVPs and one temporal MVP are utilized to form five MVPs as the candidate list for the prediction of merge mode. As depicted in Fig. 1, four spatial MVPs, in the order from left (A_1), above (B_1), above right (B_0), and left bottom (A_0) PUs are added to the candidate list. In case there are MVs exactly the same, the duplicated MVs would not be inserted. So, if the number of spatial MVPs is smaller than four, MV from above left (B_2) would be included. If the number of spatial MVPs is smaller than five, one MVP from the co-located right bottom (T_B) or the centered co-located (T_C) PU based on the availability and pre-defined order is included as temporal MVP. If the number of spatial and temporal MVPs is still fewer than five, zero MVs are used to fill in the candidate list to make it five MVPs. Fig. 3 shows the merge mode candidate list reconstruction process. Therefore, at the encoder side, rate distortion optimization (RDO) process is done to choose the best MVP from the candidate list. The best MVP would be the one with smallest rate distortion (RD) cost. And there would be an entropy codeword called merge index to indicate which MVP is used.

In SCC [1], the IBC mode [4] is used for finding repetitive patterns within the same frame as shown in Fig. 4. IBC is specially designed for screen content which contains large amount of repetitive patterns. Only the reconstructed area in the current frame can be searched by IBC. The others would be the unavailable area as they are not yet decoded or reconstructed. And the motion vector prediction for IBC is unified as the same as the conventional AMVP in inter mode and merge mode [10]. (Note that there would be no temporal MVPs for intra frames.) There would be a problem that zero MV would be an invalid MV in IBC as it points to the unavailable area. While inserting zero MV as MVPs is not a wise step for both AMVP and merge mode in IBC, the usage of IBC is very high for screen content sequences with text and graphical user interface. Mode distribution analysis was conducted using HEVC SCC reference software SCM-7.0 [15] with all-intra (AI) configuration, quantization parameter (QP) {22, 27, 32 and 37} and YUV 4:4:4 sequences according to SCC common test condition (CTC) [16] with first 100 frames encoded. Table 1 shows that the percentage of using IBC is 48.6% on average and can be up to 70.9% for mixed (MIX) and text and graphics with motion (TGM) sequences whereas the percentage of using IBC is only 1.6% on average with 4.0% at most for animation (ANI) and camera-captured (CC) sequences. Hence, we propose the decoder-side AMVP and merge mode for IBC in SCC to reduce the overhead bits for merge index and MVP.

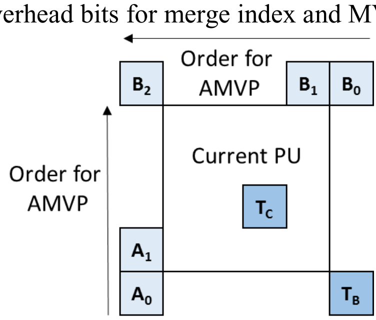

Fig. 1. MVPs for AMVP and merge mode.

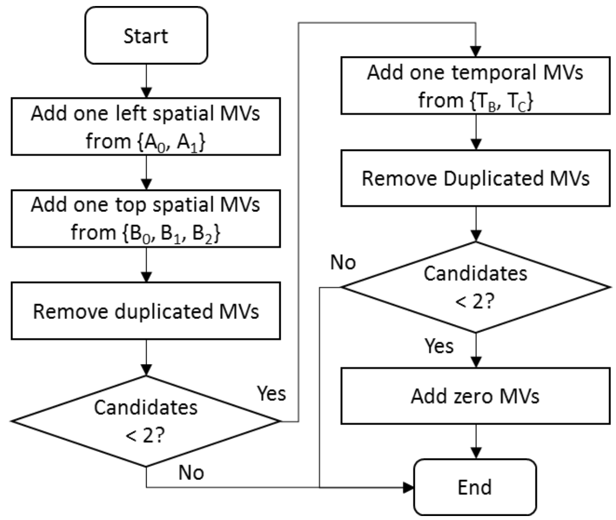

Fig. 2. AMVP candidate list reconstruction process.

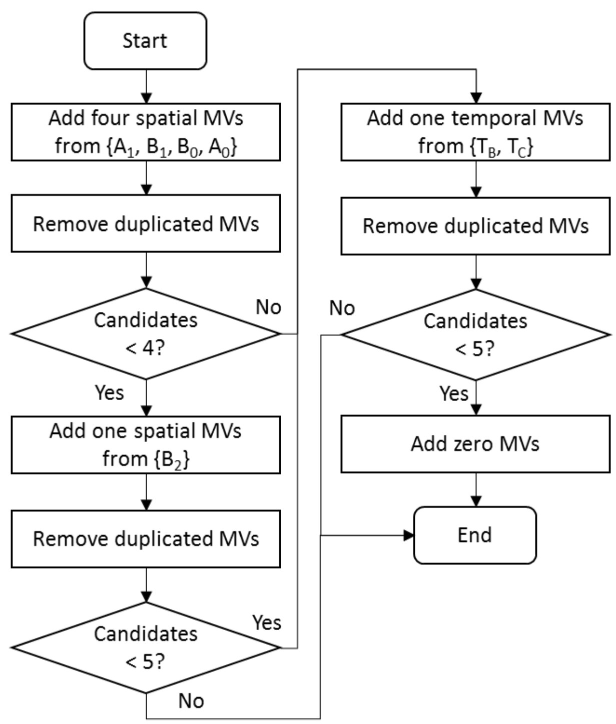

Fig. 3. Merge mode candidate list reconstruction process.

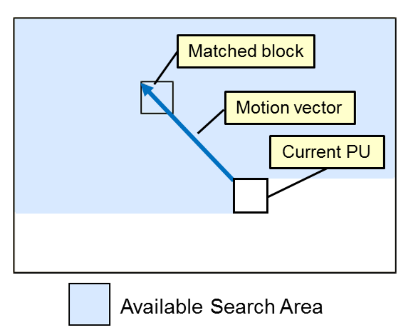

Fig. 4. Illustration of IBC mode to search for repetitive pattern within the same frame.

3. PROPOSED APPROACHES

3.1. Decoder-side AMVP

For AMVP in IBC, if two MVPs are also zero MVs, then the bit for indicating which MVP to be used is redundant. This is a common case when the neighbor PUs are not IBC coded, i.e. the neighbor PUs are coded as the conventional intra mode and the PLT mode. Table 2 tabulates the probability of all MVPs being zero MVs when the current PU is IBC coded, P(AllZeroMV), at a given coding unit (CU) size using the same coding condition as described in the previous section. It is noted that IBC mode using AMVP is disabled for 64×64 CU in SCM-7.0 as repetitive patterns tend to appear in small CU size, and ANI and CC sequences are not analyzed as they only contain 1.6% IBC on average as in Table 1. From Table 2, it is observed that P(AllZeroMV) is 12.6%, 14.8% and 5.8% on average, also up to 36.8%, 44.3% and 17.2% for 32×32, 16×16 and 8×8 CU respectively. And actually, AllZeroMV is one of the cases for two MVPs having equal MVs, AllEqualMV, in which AllEqualMV also induces the redundant bits for MVP selection. By this fact, we further propose in AMVP that, when the condition, AllEqualMV, is satisfied, the bit indicating which MVP is selected would be skipped, in order to improve the coding efficiency, as below:

$$MvBit_{AMVP} = \begin{cases} Bit_{MVD} & \text{if } AllEqualMV \\ Bit_{AMVP\_Idx} + Bit_{MVD} & otherwise \end{cases} \quad (1)$$

where $MvBit_{AMVP}$, Bit_{AMVP_Idx}, and Bit_{MVD} are the bits for MV in AMVP, MVP index and MVD respectively. Thereby, at the decoder, if it is IBC mode, MVPs are firstly checked if they are all equal MVs before decoding or skipping the MVP index.

3.2. Decoder-side merge mode

For merge mode in IBC, it is impossible to have zero MVs for all five MVPs. It is because by using merge mode, the MVP would be directly used for MC in which zero MV points to area that not yet reconstructed and thereby cannot be used in merge mode. Nevertheless, if there is only one MVP which is non-zero MV while other four MVPs are zero MVs, we can skip the merge index coding since there is only one single choice. This can be a case when all of the neighbor PUs are have the same MV or coded as other modes. According to Fig. 3, after removing the duplicated MVs, there would be only one non-zero MV left. Table 3 shows the probability of, among five MVPs, only one single MVP is non-zero when IBC-coded, P(SingleNonZeroMV), at a given CU size using the same coding condition as in previous section. As tabulated in Table 3, P(SingleNonZeroMV) is 47.7%, 45.5%, 39.3% and 29.9% on average, also up to 81.8%, 79.6%, 78.9% and 50.8% for 64×64, 32×32, 16×16 and 8×8 CU respectively, which is quite a large figure. As a result, we propose in merge mode that, when there is only one single

Table 1. Mode distribution (%) in SCM-7.0.

Sequences	Type	Intra	PLT	IBC
Basketball_Screen	MIX	43.351	10.063	46.586
MissionControlClip2	MIX	55.893	4.385	39.721
MissionControlClip3	MIX	43.961	7.324	48.714
ChineseEditing	TGM	14.561	37.490	47.949
sc_console	TGM	10.061	22.213	67.726
sc_desktop	TGM	13.383	17.544	69.073
sc_flyingGraphics	TGM	12.352	16.716	70.933
sc_map	TGM	59.843	25.272	14.885
sc_programming	TGM	37.036	13.208	49.756
sc_SlideShow	TGM	79.946	6.603	13.452
sc_web_browsing	TGM	24.133	9.937	65.930
sc_robot	ANI	93.266	2.781	3.953
EBURainFruits	CC	99.300	0.031	0.669
Kimono1	CC	99.803	0.010	0.187
Average (MIX+TGM)		**35.865**	**15.523**	**48.611**
Average (ANI+CC)		**97.457**	**0.941**	**1.603**
Average (Overall)		**49.064**	**12.398**	**38.538**

Table 2. Probability of all MVPs having zero MVs for AMVP, P(AllZeroMV).

MIX+TGM	32×32 (%)	16×16 (%)	8×8 (%)
Average	12.641	14.792	5.772
Up To	36.765 (sc_SlideShow)	44.338 (sc_SlideShow)	17.246 (sc_SlideShow)

Table 3. Probability of only one single MVP being non-zero MV for merge mode, P(SingleNonZeroMV).

MIX+TGM	64×64 (%)	32×32 (%)	16×16 (%)	8×8 (%)
Average	47.684	45.522	39.309	29.946
Up To	81.793 (sc_web_browsing)	79.597 (sc_map)	78.915 (sc_map)	50.813 (sc_SlideShow)

MVP being non-zero among five MVPs, the coding of merge index, *Merge_Idx*, is redundant and would be skipped to improve the coding efficiency as follows:

$$MvBit_{Merge} = \begin{cases} 0 & \text{if } SingleNonZeroMV \\ Bit_{Merge\_Idx} & otherwise \end{cases} \quad (2)$$

where $MvBit_{Merge}$, and Bit_{Merge_Idx} are the bits for MV in merge mode and merge index respectively. Similar to our proposed decoder-side AMVP, at the decoder, if it is IBC merge mode, MVPs are firstly checked if there is only one non-zero MV before decoding or skipping the merge index.

4. EXPERIMENTAL RESULTS

To evaluate the performance of the proposed algorithm, we perform simulations using the HEVC SCC reference software SCM-7.0 [15] with the coding conditions already mentioned in Section 2. The experiments were performed on the computer Dell Precision T1700 with Intel i7-4770 3.40GHz processor and 16GB memory. For the sake of simplicity, the conventional HEVC SCC extension is denoted as SCC, whereas our proposed decoder-side AMVP and decoder-side merge mode in Section 3.1 and 3.2 are denoted as DSAMVP and DSMERGE respectively.

Table 4 shows the Bjontegaard delta bitrate (BD-rate) [17] for DSAMVP and DSAMVP+DSMERGE against the conventional SCC. With our DSAMVP+DSMERGE, 0.11% and 0.10% on average, and up to 0.25% and 0.21% BD-rate reduction can be achieved for YUV and RGB MIX+TGM sequences respectively. And there is only 0.02% and 0.01% BD-rate reduction for YUV and RGB ANI+CC sequences respectively which has negligible influence to ANI+CC sequences since IBC mode is rarely used as tabulated in Table 1.

Table 5 tabulates the average encoding time and average decoding time for DSAMVP and DSAMVP+DSMERGE against SCC. With our DSAMVP+DSMERGE, there is slight encoding time increase of 0.16% and decrease of 0.43% for YUV and RGB sequences respectively. The decrease might be due to the skipping of merge index entropy coding in (2). And there is decoding time increase of only 2.41% and 0.54% for YUV and RGB sequences respectively. It is because for every PU using IBC mode, the conditions in (1) and (2) must be checked before decoding or skipping of codeword. It can be concluded that the impact to encoding and decoding complexity is negligible.

Our proposed approaches are also compared with other decoder-side redundant bit removal approaches, which shown in Table 6. [18] proposed to remove Bit_{Merge_Idx} by template matching in HEVC. [19] and [20] proposed to have decoder-side ME in HEVC and H.264 respectively so as to remove Bit_{MVD}. The decoder complexity would be high for [18-20]. [21], [22] and [23] suggested to remove the bits for intra prediction direction in SCC, HEVC and depth coding respectively with reasonable complexity. The work in [24] reduces the weighted prediction (WP) [25-26] headers by predicting the weights and offsets for Scalable HEVC (SHVC) only when information in inter and inter-layer frames is available at both encoder and decoder sides. Therefore, our proposed approach is reasonably good with up to 0.25% BD-rate reduction on the top of SCC without any computational complexity impact while the conventional IBC has already obtained up to 31.3% BD-rate reduction against SCC without IBC [1].

On the other hand, if all of the decoder-side coding techniques can be applied together, there would be a considerable coding gain. It is worthy to have the research work on the decoder-side coding techniques and it is possible, say for example, to have an additional profile, decoder-side profile, to enable or disable all those decoder-side techniques.

Table 4. BD-rate (%) against SCC.

Sequences	YUV		RGB	
	DSAMVP	DSAMVP+ DSMERGE	DSAMVP	DSAMVP+ DSMERGE
Basketball_Screen	0.012	-0.023	0.035	-0.049
MissionControlClip2	-0.027	-0.124	-0.041	-0.095
MissionControlClip3	-0.029	-0.109	-0.025	-0.082
ChineseEditing	-0.020	-0.084	-0.051	-0.074
sc_console	-0.018	-0.199	-0.030	-0.176
sc_desktop	0.009	-0.062	-0.051	-0.209
sc_flyingGraphics	-0.052	-0.220	-0.008	-0.155
sc_map	-0.065	-0.084	-0.011	0.034
sc_programming	-0.053	-0.110	0.005	-0.097
sc_SlideShow	-0.186	0.020	-0.051	-0.029
sc_web_browsing	-0.217	-0.250	0.135	-0.106
sc_robot	-0.050	-0.043	0.012	-0.011
EBURainFruits	-0.008	-0.009	0.001	-0.011
Kimono1	-0.009	-0.007	-0.008	-0.011
Average (MIX+TGM)	**-0.059**	**-0.113**	**-0.008**	**-0.095**
Average (ANI+CC)	**-0.022**	**-0.020**	**0.001**	**-0.011**
Average (Overall)	**-0.051**	**-0.093**	**-0.006**	**-0.077**

Table 5. Encoding and decoding time (%) against SCC.

MIX+TGM+ANI+CC (Overall)	YUV		RGB	
	DSAMVP	DSAMVP+ DSMERGE	DSAMVP	DSAMVP+ DSMERGE
Encoding Time	**1.110**	**0.164**	**1.165**	**-0.430**
Decoding Time	**1.912**	**2.407**	**0.618**	**0.535**

Table 6. Comparison with other decoder-side techniques.

Approaches	BD-rate (%)	Encoding Time (%)	Decoding Time (%)
[18] HEVC	-0.73 on average	-	-
[19] HEVC	-0.6 to -1.1	3 to 7	6 to 15
[20] H.264	-3.32 to -14.38	-	18 to 6551
[21] SCC	-0.076 on average	-0.4 to -53.3	-
[22] HEVC	-0.04 to -0.18	-7.6 to -34.1	6 on average
[23] Depth Coding	-3.6 on average (Depth Map Only)	-31.5 on average	-
[24] SHVC	-0.88 to -2.28 on average	-	-

5. CONCLUSIONS

In this paper, we propose a novel decoder-side merge/skip mode and AMVP for intra block copy (IBC) mode in SCC. Redundant motion vector coding bits are removed by considering the unreasonable zero motion vector predictors in the candidate lists for merge mode and AMVP. Experimental results show that up to 0.25% of BD-rate reduction is obtained with negligible impact to encoding time and decoding time. We believe that by combining several decoder-friendly decoder-side coding techniques, a significant bitrate reduction can be achieved with the balance of computational complexity. It is strongly desired to design other decoder-side coding techniques in SCC.

6. ACKNOWLEDGEMENTS

This work was supported by the Centre for Signal Processing, Department of Electronic and Information Engineering, The Hong Kong Polytechnic University (PolyU), and a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China (Grant No. PolyU 152016/14E).

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