Enhanced Hash-based Intra Block Copy for HEVC Screen Content Coding using Sucessive Elimination Algorithm

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***Abstract*—An efficient algorithm is proposed not only to reduce the computation cost of the hash-based intra block copy (IBC), but also to achieve the Bjontegaard delta bit rate (BDBR) gain for High Efficiency Video Coding standard (HEVC) screen content coding(SCC). Recently, the HEVC Screen Content Coding Draft 6 was published including several new tools. Among those, hash-based intra block copy shows the high coding gain but it has a massive computational complexity even though it is adopted as a fast algorithm for global block search for IBC mode. The proposed algorithm suggests the effective way to calculate the lower bound for rate-distortion (RD) cost when performing the hash-based IBC process and to eliminate the impossible candidates earlier. Experimental results show that about 50% on the average and up to 86.80% of the search points can be early terminated as well as 0.21% on the average BDBR saving can be achieved compared to HM-16.8+SCM-6.1.**

Keywords; HEVC; Screen content coding(scc); Intra Block copy(IBC); Hash.

I. INTRODUCTION

High Efficiency Video Coding standard (HEVC) [1] is the most recent international video coding standard jointly developed by Joint Collaborative Team on Video Coding (JCT-VC) and it was finalized in January 2013. HEVC is able to achieve around 50% bit-rate reduction under the equivalent subjective visual quality circumstances, compared with H.264/MPEG-4 AVC standard [2][3].

Recently, on the other hand, there has been a proliferation of applications which utilize the computer generated contents, such as wireless display, remote desktop, external display interfacing, and cloud computing, etc. [4]. However, the type of video content used in these applications has different characteristics compared with that of the camera-captured content, such as containing no sensor noise, having large uniformly flat areas, repeated patterns, and a limited number of different colors and so on.

Even though there are several sequences that contain screen contents in the common test sequences, such as Class F, HEVC may not be efficient for the sequences whose characteristics are different from the camera-captured natural video contents because it was developed with a main focus on dealing with camera-captured natural video contents. Accordingly, there have been requirements for coding of screen content. In order to reflect these requirements, the MPEG Requirements subgroup published a set of requirements for an extension of HEVC for coding of screen content in January 2014 [4] and currently the HEVC Screen Content Coding (SCC) Draft 6 was published in February 2016 [5][6].

In HEVC-SCC, 4 major techniques/tools have been introduced: Palette mode, Adaptive colour transform (ACT), Adaptive motion vector resolution, and Intra block copy (IBC). Palette mode utilizes the observation that a number of different colour value frequently exist for screen content. A lot of HEVC-SCC test materials consist of RGB colour format or YCbCr 4:4:4 format, whose inter-colour component correlation is very high. In order to remove inter-colour component redundancy, ACT has been introduced in SCC. Unlike camera captured content, there is no need to use fractional motion compensation for much screen content. For this reason, adaptive motion vector has adopted in SCC. There are a lot of repeated patterns such as characters in screen content, so the motion estimation and compensation within the current picture can be effective. IBC is the technique that conducts the motion estimation and compensation within the current picture as shown in Fig. 1.

In HEVC-SCC Draft 6, there are two kinds of block vector search method for IBC: local search mode and global search mode and hash-based block vector search technique has been adopted for global search mode. This paper provides an overview of technical issues of IBC and presents a tool for improving IBC, especially hash-based block vector search.

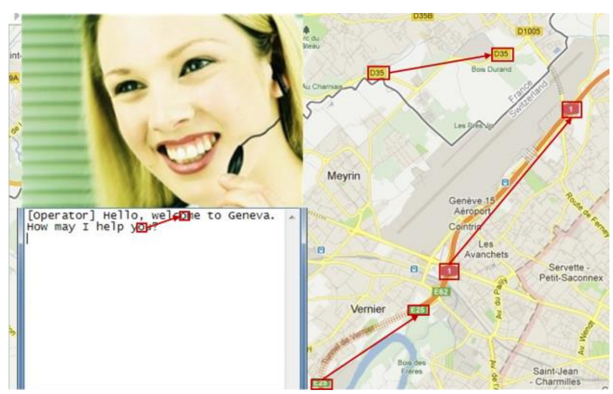

Figure 1. An example of IBC from sc_map video sequence

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This paper is organized as follows: Section II describes a technical features of IBC as a conventional algorithm. Section III presents the proposed algorithm. Section IV discusses the experiment results and the conclusion is set forth in Section V.

II. INTRA BLOCK COPY (IBC) IN HEVC-SCC DRAFT 6

Basically, IBC is the technique that conducts the motion estimation (ME) and compensation within the current picture. Block matching is performed in order to find the optimal block vector and to calculate the lowest rate-distortion (RD) cost like ME but within a current picture. On the other hand, there are two kinds of IBC modes in SCC: local block vector search and global block vector search for IBC mode. In SCC, a local area search is performed first and a global search is followed. Comparing RD cost from both search, choose the block vector with the minimum RD cost.

A. Local block vector search for IBC mode

In this step, there are two steps find the optimal block vectors (BVs). First, find the four best BVs according to their RD cost, where

$$RD\_\cos t = SAD_{luma} + \lambda \times BV_{bits} \qquad (1)$$

within 2 CTU for the local search as depicted in Fig. 2 where BV_{bits} is the number of bits needed to signal the BV. In this step, only the SAD of the luma component is used. For the chosen four best BVs, additional RD cost is calculated as

$$RD\_\cos t = SAD_{luma} + SAD_{chroma} + \lambda \times BV_{bits} \qquad (2)$$

, in order to find the locally optimal block vector BV_{opt}^{local}. The RD cost corresponding to BV_{opt}^{local} is denoted by $RD\_\cos t_{opt}^{local}$.

B. Global block vector search for IBC mode

Global block vector search is conducted for 8x8 and 16x16 blocks. As shown in Fig. 3, the entire reconstructed current picture before loop filtering is the global search prediction area. For 16x16 blocks, a one-dimensional search is performed over the entire reconstructed current picture, as shown in Fig. 4. For the horizontal search, block matching is performed only in the horizontal direction that means vertical components of BVs are zero with the same height of the current block and the vertical search is performed in the same manner.

For 8x8 PUs, a hash-based full picture search is used to search the optimal BV. The 16-bit hash entries for the current block and the reference block are calculated using the original sample values. Let Grad denote the gradient of the 8x8 block and let dc0, dc1, dc2, and dc3 denote the DC values of the four 4x4 sub-blocks of the 8x8 block. Then, the 16-bit hash entry H is calculated as:

$$\begin{aligned} H = {} & MSB(dc0,3) << 13 + MSB(dc1,3) << 10 + \\ & MSB(dc2,3) << 7 + MSB(dc2,3) << 4 + \\ & MSB(Grad,4), \end{aligned} \qquad (3)$$

where MSB(X,n) represents the n most significant bits of X.

The procedure of hash-based IBC is as follows: First, the hash-value of the current PU is calculated. Search the blocks which have the same hash value with the current PU in the pre-calculated hash list. Then, the blocks that have the same hash value with that of the current block perform the RD cost and choose the eight best BVs according to (1). For the chosen eight best BVs, additional RD cost is calculated using (2) in order to find the BV_{opt}^{global}.

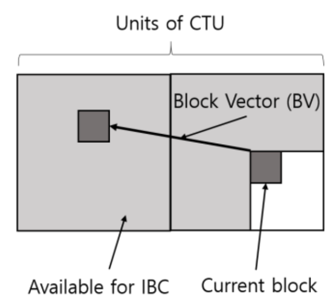

Figure 2. Local block vector search prediction area

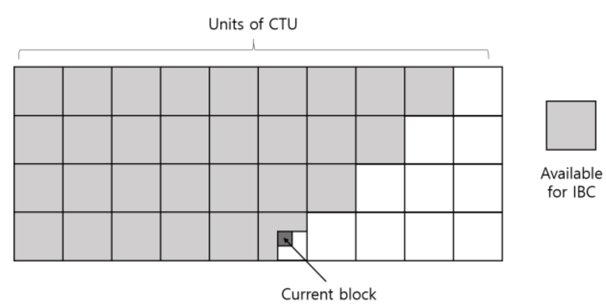

Figure 3. Global block vector search prediction area

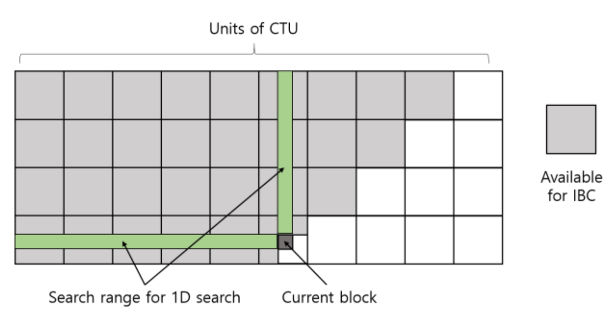

Figure 4. A one-dimensional search prediction area for 16x16 blocks

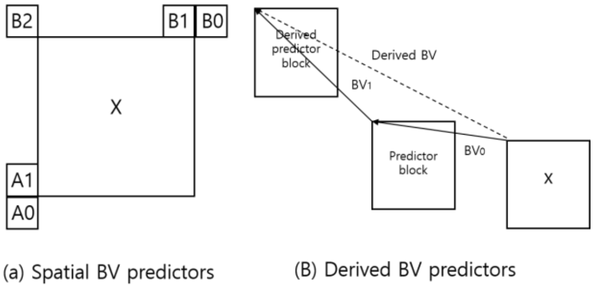

Figure 5. IBC prediction area

C. Fast block vector search for IBC mode

If the residual of inter prediction is not zero, some fast search and early termination methods are employed, between evaluating the RD cost of inter mode and intra mode. It is applied only to 2Nx2N partition of various CU sizes. If the residue of fast IBC search is not zero, then regular intra mode will be performed as described in Sections A and B.

The SAD-based RD costs of using a set of BV predictors are calculated in the fast search. As shown in Fig. 5, the set includes the five spatial neighboring BV as used in inter merge mode and the last two coded BVs. In addition, the derived BVs of the block pointed to by each of the aforementioned BV predictors are also included.

III. PROPOSED ALGORITHM

Hash-based IBC mode for the 8x8 PU has a critical role in SCC. Compared with SCC without hash-based IBC, up to 75% Bjøntegaard Distortion bitrate (BD-BR) gain can be achieved. On the other hand, even though the main purpose of using hash-based search is to speed up the full picture search, it has a massive computation burden when there are a number of blocks in the hash list. For example, over 70 thousand times RD cost calculations are performed on the average for 8x8 PU, when we encode "sc_wordEditing_1280x720_8bit_444" sequence under the intra_main_SCC condition. In order to alleviate this, we apply the concept of the successive elimination algorithm (SEA) [7] for the 8x8 PUs which are used for hash-based search.

The derivation of the SEA starts from the following basic triangular inequalities,

$$\begin{cases} f_c(i,j) - f_r(i-x, j-y) \le \left| f_c(i,j) - f_r(i-x, j-y) \right| \\ f_r(i-x, j-y) - f_c(i,j) \le \left| f_c(i,j) - f_r(i-x, j-y) \right| \end{cases}, \quad (4)$$

where $f_c(i,j)$ and $f_r(i,j)$ denote the intensity of the pixel with coordinate (i,j) in the current picture and the reference picture, (x,y) represents the displacement of the BVs, respectively.

By using (4), it can be easily shown that the following relation holds:

$$\begin{aligned} &\left| \sum_{i,j=0}^{N} f_c(i,j) - \sum_{i,j=0}^{N} f_r(i-x, j-y) \right| \\ &\quad \le \sum_{i,j=0}^{N} \left| f_c(i,j) - f_r(i-x^*, j-y^*) \right| = SAD(x^*, y^*), \end{aligned} \quad (5)$$

where (x^*, y^*) denotes the displacement of the optimal BV. This means that the difference of the sum norms of the current block and the reference block cannot exceed the SAD value of the search point, so we can distinguish the impossible candidate using the sum norms and SAD value. In this case, $SAD(x^*, y^*)$ and (x^*, y^*) can be updated by $SAD(x, y)$ and (x, y), respectively, if $SAD(x, y)$ is less than $SAD(x^*, y^*)$. Also, applying (5) into (1), then it can be easily demonstrated the following inequality:

$$\begin{aligned} &\left| \sum_{i,j=0}^{N} f_c(i,j) - \sum_{i,j=0}^{N} f_r(i-x, j-y) \right| + \lambda \times BV_{bits} \\ &\quad \le RD\_\cos t_{\min}. \end{aligned} \quad (6)$$

Note that all the procedure of the proposed algorithm is applied when the hash value is matched. The procedure of the proposed algorithm is as follows: Calculate the $\lambda \times BV_{bits}$ first and then check (6) with the sum norms and the value of $RD\_\cos t_{\min}$. If the condition does not hold, discard the search point and move on to next search point. Once the search point is skipped, that point cannot be included as a candidate set aforementioned in Section II. C.

Note that the sum norm for each block has been already calculated when calculating the 16-bit hash entry H in (3). In other words, there is no additional computation to get the sum norms of the current block and reference blocks.

IV. EXPERIMENT RESULTS

In order to demonstrate the coding efficiency of the proposed algorithm, we simulated five sequences in the common test conditions (CTC) used during the development of HEVC-SCC [8] and a sequence from the HEVC CTC in Class F as listed in Table I under the intra_main_scc configuration condition. HM-16.8+SCM-6.1 was modified to include the proposed algorithm. 22, 27, 32, and 37 are set for QPs.

TABLE I. TEST SEQUENCES

Resolution	**Sequence name**	**YCbCr color format**
1920x1080	sc_desktop_1920x1080_60_8bit	4:4:4
1920x1080	MissionControlClip3_1920x1080_60_8b444	4:4:4
1280x720	sc_web_browsing_1280x720_30_8bit	4:4:4
1280x720	sc_map_1280x720_30_8bit	4:4:4
1280x720	sc_wordEditing_1280x720_30_8bit	4:4:4
1280x720	slideEditing_1280x720_30	4:2:0

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TABLE II. PERFORMANCE COMPARISON BETWEEN HM-16.8 AND HM-16.8+SCM-6.1.

Sequence name	BD-BR (%)
sc_desktop_1920x1080_60_8bit	-84.01
MissionControlClip3_1920x1080_60_8b444	-28.24
sc_web_browsing_1280x720_30_8bit	-51.32
sc_map_1280x720_30_8bit	-80.88
sc_wordEditing_1280x720_30_8bit	-68.54
slideEditing_1280x720_30	-48.50
Average	-60.25

TABLE III. PERFORMANCE COMPARISON WITH VERSUS WITHOUT HASH-BASED IBC FOR HM-16.8+SCM-6.1.

Sequence name	BD-BR (%)
sc_desktop_1920x1080_60_8bit	-75.56
MissionControlClip3_1920x1080_60_8b444	-4.12
sc_web_browsing_1280x720_30_8bit	-27.00
sc_map_1280x720_30_8bit	-67.90
sc_wordEditing_1280x720_30_8bit	-54.19
slideEditing_1280x720_30	-21.54
Average	-41.72

TABLE IV. PERFORMANCE COMPARISON BETWEEN HM-16.8+SCM-6.1 AND THE PROPOSED ALGORITHM.

Sequence name	BD-BR (%)
sc_desktop_1920x1080_60_8bit	-0.62
MissionControlClip3_1920x1080_60_8b444	0.00
sc_web_browsing_1280x720_30_8bit	-0.13
sc_map_1280x720_30_8bit	-0.26
sc_wordEditing_1280x720_30_8bit	-0.22
slideEditing_1280x720_30	0.00
Average	-0.21

TABLE V. EARLY TERMINATION RATIO COMPARED TO HM-16.8+SCM-6.1 (%)

Sequence name	Ratio (%)
sc_desktop_1920x1080_60_8bit	57.25
MissionControlClip3_1920x1080_60_8b444	26.40
sc_web_browsing_1280x720_30_8bit	86.80
sc_map_1280x720_30_8bit	42.55
sc_wordEditing_1280x720_30_8bit	45.50
slideEditing_1280x720_30	35.43
Average	48.99

Table II shows the bit-rate savings SCC tools over HM-16.8 for intra main configuration. Note that negative number indicates the BD-BR saving. BD-BR savings in the range of 28.24% to 84.01% and 60.25% on the average can be observed.

Aforementioned in Section III, hash-based global IBC search has an important role in SCC as shown in Table III. Except some sequences like “MissionControlClip3”, BDBR saving rate is quite high; about 40% BDBR saving can be observed.

Table IV shows the performance comparison between HM-16.8+SCM-6.1 and the proposed algorithm. Even though we proposed a kind of an early termination methods over hash-based IBC, we can achieve the BDBR saving up to 0.62% and 0.21% on the average. The interesting point is that the sequences which have the higher coding gain by using hash-based IBC also have the higher coding gain for the proposed algorithm. We can obtain the coding gain by eliminating the impossible search points that may be a bad influence on BV predictors from as a candidate set aforementioned in Section II. C.

It is demonstrated that the impossible search point can be effectively removed by checking (6) as shown in Table V. The impossible candidates are removed up to 86.80% and about 50% on the average.

V. CONCLUSION

In this paper, enhanced hash-based intra block copy algorithm using successive elimination algorithm is proposed, after analyzing the conventional IBC technique in HEVC SCC Draft 6, especially hash-based IBC. The proposed algorithm suggests the efficient way to calculate the lower bound for RD cost when performing the hash-based IBC process and to eliminate the impossible candidates earlier. Experimental results show that about 50% on the average and up to 86.80% of the search points can be early terminated as well as 0.21% on the average BDBR saving can be achieved compared to HM-16.8+SCM-6.1.

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