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Early Termination of Block Vector Search for Fast Encoding of HEVC Screen Content Coding

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** Short Paper*

***Abstract*:** This paper proposes an early termination method of a block vector search for fast encoding of high efficiency video coding (HEVC) screen content coding (SCC). In the proposed algorithm, two blocks indicated by two block vector predictors (BVPs) were first employed as an intra block copy (IBC) search. If the sum of absolute difference (SAD) value of the block is less than a threshold defined empirically, an IBC BV search is terminated early. The initial threshold for early termination is derived by statistical analysis and it can be modified adaptively based on a quantization parameter (QP). The proposed algorithm is evaluated on SCM-2.0 under all intra (AI) coding configurations. Experimental results show that the proposed algorithm reduces IBC BV search time by 29.23% on average while the average BD-rate loss is 0.41% under the HEVC SCC common test conditions (CTC).

***Keywords*:** HEVC, SCC, IBC, Early termination, Fast encoding

1. Introduction

Screen content videos are used widely in various applications, such as remote education, video conferencing and animation. In addition, the demand for screen contents has increased steadily in various markets due to the development of mobile devices with high specifications and digital contents production tools. On the other hand, conventional coding tools including high efficiency video coding (HEVC) [1], which was released in January 2013 cannot compress screen content videos efficiently. Conventional coding tools were developed based on the characteristics of natural videos. For example, the intra prediction method of HEVC has 35 prediction modes composed of DC, planar, and 33 angular modes to achieve better prediction compared to the previous video codec, H.264/AVC [2]. On the other hand, a prediction unit (PU) can have only one of 35 prediction modes, and the reference samples for the prediction are restricted to the neighboring samples of the current PU. In addition, reference samples are filtered before they can be used as predictors. Therefore, the conventional intra prediction method cannot compress efficiently for screen contents consisting of many edges, graphics, and text data, as shown in Fig. 1. In this regard, the study for screen content coding (SCC) had been required steadily and the standardization of HEVC SCC have started since January 2014.

Call for proposals (CfP) [3] for HEVC SCC was released in January 2014 by ISO/IEC/JTC1/SC29/WG11 and ITU-T SG16 Q6/16. Seven documents were registered, and the standardization of HEVC SCC have progressed based on the document [4] showing the best coding performance. Standard meetings have been held twice at present 2015, and the final draft international standard (FDIS) for HEVC SCC will be released in February 2016.

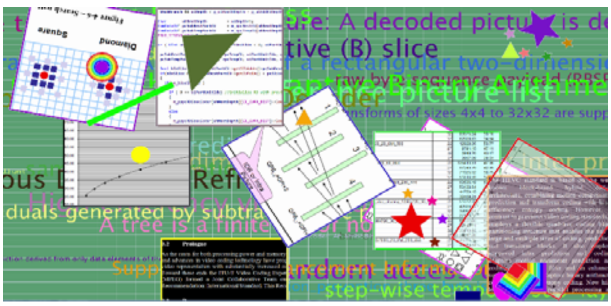


Fig. 1. Test sequence 'sc_flyingGraphics_1920x1080_60_8bit_444' of CTC for HEVC SCC.

HEVC SCC includes HEVC range extensions (RExt) [5], which was released in July 2014, and several methods were adopted during the standard meeting, such as intra block copy (IBC), palette mode, and adaptive colour transform (ACT). This paper concentrates on the IBC techniques and the detail description of other methods can be found at the HEVC SCC draft text [6].

The IBC is a prediction method that finds a matched block within a current frame with the current PU, as shown in Fig. 2. An IBC on/off can be controlled at the coding unit (CU) level and four PU partitioning modes (2N× 2N, 2N× N, N× 2N, and N× N) are supported. A block vector (BV) is represented for indicating the matched block and BV information is signaled to the decoder side. The amount of BV data is significant because it is signaled at the PU-level; therefore, the block vector prediction method is used to reduce the BV data.

Two block vector predictors (BVPs) are constructed as candidate predictors for the block vector prediction method. Advanced motion vector prediction (AMVP) is employed first to construct the BVPs. If there is an empty space in the BVPs after employing AMVP, the two last block vector predictors are used. If the empty space is still exist, then it is filled with default vectors. A detailed description related to the process of BVP construction order can be found elsewhere [7]. After the block vector prediction method, the block vector difference (BVD), which is calculated by the difference between a BV and a BVP is coded by the 3rd exponential golomb coding method, and the detail part can be referred at this document [8].

The IBC provides a significant coding gain up to 69.39% BD-rate [9]; however, the computational complexity is increased by more than 30%. On the other hand, the prospective primary markets of HEVC SCC are video conferencing, desktop sharing, and remote education in real time. Therefore, fast algorithm for IBC should be considered.

In this paper, an early termination algorithm to reduce the computational complexity of IBC is proposed. The proposed algorithm employs one of the blocks indicated by the BVPs at first. If the sum of absolute difference (SAD) value is less than a threshold, which is defined empirically, IBC BV search is terminated early.

The remainder of this paper is organized as follows. The next section presents the conventional IBC fast encoding methods. Section 3 describes the early termination algorithm of IBC BV search proposed in this paper. The experimental results are given in Section 4, and this paper is concluded in the last section.

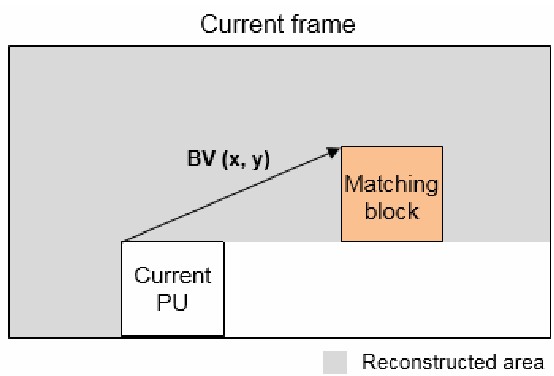


Fig. 2. Example of IBC.

2. Related Work

Conventional IBC fast encoding methods have been attempting to reduce the burden of IBC encoding complexity. The CU size restriction [10] method was suggested because the coding efficiency of IBC is not efficient at a large CU size (e.g. 64× 64 and 32× 32). In addition, PU partitioning mode except for 2N× 2N is only employed at the smallest CU size.

To reduce the block vector search time, the 1-D search and hash search [11] methods were suggested. A 1-D search method finds the matched block in the horizontal and vertical directions sequentially. The hash search method finds the matched block in the list of hash entries constructed during the encoding of the current frame. In addition, the IBC skip method [12] based on the cost calculated at the intra prediction mode was proposed.

The SCC reference model (SCM) 2 [13] supports all these fast encoding methods [10-12]; however, the IBC complexity still accounts for over 30% of the total encoding time.

3. The Proposed Scheme

In the proposed algorithm, two blocks indicated by BVPs are first used for the block vector search. If the SAD value at the block is less than a threshold, the block vector search is terminated. The threshold value is defined based on statistical experimental results, as described in this section.

Table 1 lists the proportion of the BVD whose value is zero ($pBVD_z$) on all intra (AI) coding configuration under common test conditions (CTC) [14]. The average $pBVD_z$ ratios were 52.16%, 46.30%, and 19.07% on the sequences of text and graphic with motion (TGM), mixed contents (M) and, camera captured (CC) categories, respectively. The BVD zero ratio is relatively high on the TGM and M category sequences for the entire quantization parameter (QP) range; however, the CC category sequences have a low zero BVD ratio. Because the IBC coding mode is not efficient on CC category, and thus there are fewer block vectors that can be used as BVPs [15].

The average $pBVD_z$ is more than a half a percentage on the TGM category sequences, which means that the matched blocks are found at one of the BVPs over 50%. Therefore, the IBC BV search time can be reduced based on this result and the following experimental results were analyzed to find the condition when the zero BVD occurs.

Fig. 3 shows the SAD distribution of the range from 0 to 100 for BVD_z and BVD_{nz} of the *sc_console* sequence on AI coding configuration. BVD_z represents the SAD distribution of BVD whose values are zero, and BVD_{nz} is

Table 1. Proportion of BVD_z .

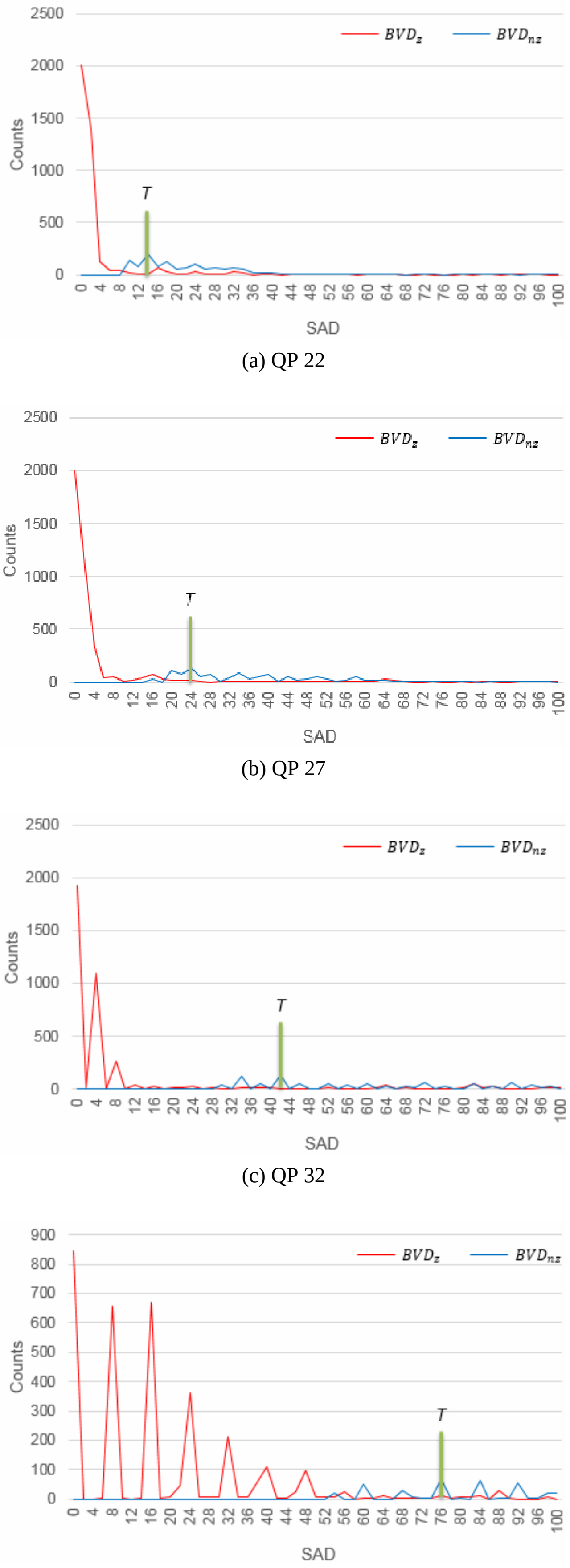
Sequence	Category	QP	$pBVD_z$
sc_flyingGraphics	TGM	22	49.31%
		27	47.95%
		32	48.11%
		37	49.19%
sc_desktop	TGM	22	51.88%
		27	51.91%
		32	53.18%
		37	54.72%
sc_console	TGM	22	53.73%
		27	53.75%
		32	54.88%
		37	57.32%
MissionControlClip3	M	22	42.20%
		27	44.58%
		32	47.29%
		37	51.13%
EBURainFruits	CC	22	9.69%
		27	8.80%
		32	10.96%
		37	21.04%
Kimono1	CC	22	17.98%
		27	23.60%
		32	23.68%
		37	36.80%
Average (TGM)			52.16%
Average (M)			46.30%
Average (CC)			19.07%
Average			40.15%

the SAD distribution of BVD with non-zero values. BVD_z is concentrated in the lower SAD value than that of BVD_{nz} and the SAD distribution shape of all tested sequences is similar to that shown in Fig. 3. Based on the statistical results, the threshold can be defined for the early termination condition.

Initially, each initial threshold for the test sequences is calculated by the peak counted SAD value of BVD_{nz} in the range from 0 to average SAD (SAD_{avg}) of BVD_{nz} as Eq. (1). Note that if a large SAD value is used as a threshold, there will be a greater chance of skipping the block vector search; however, the miss-rate of fault skipping is also increased. In the experimental results, the peak value in the range from 0 to SAD_{avg} has relatively high coding gains in a point of the BD-rate and computational complexity.

$$T = \max_{SAD}\left\{BVD_{nz}\left(SAD\right)\right\},\ 0 \le SAD \le SAD_{avg} \quad (1)$$

In addition, it was found that T is changed constantly as



(a) QP 22

(b) QP 27

(c) QP 32

(d) QP 37

Fig. 3. SAD distribution for BVD_z and BVD_{nz} .

QP is increased. The increase in T is approximately $2^{1/6}$ as QP is increased by 1, and it can be thought as the QP of HEVC, which is designed linearly as an increment of $2^{1/6}$ between the QP and video quality. Therefore, the adaptive threshold (T_{QP}) can be defined as Eq. (2).

$$T_{QP} = T_i \times 2^{(QP_c - QP_i)/6} \tag{2}$$

The algorithm is proposed, as shown in Fig. 4, based on the defined threshold. IBC coding is started if the CU depth is larger than 1 (E.g. 16×16 and 8×8 CU). Two BVPs are constructed and the SAD value is calculated at those candidate blocks indicated by BVPs. If the smallest SAD value of the candidate blocks is less than T_{QP}, which is changed adaptively by QP, the remaining search algorithms, such as the full search and hash search are skipped. In this way, the proposed algorithm can reduce the computational complexity, especially to the TGM category sequences that employ IBC mode much more than the other category sequences.

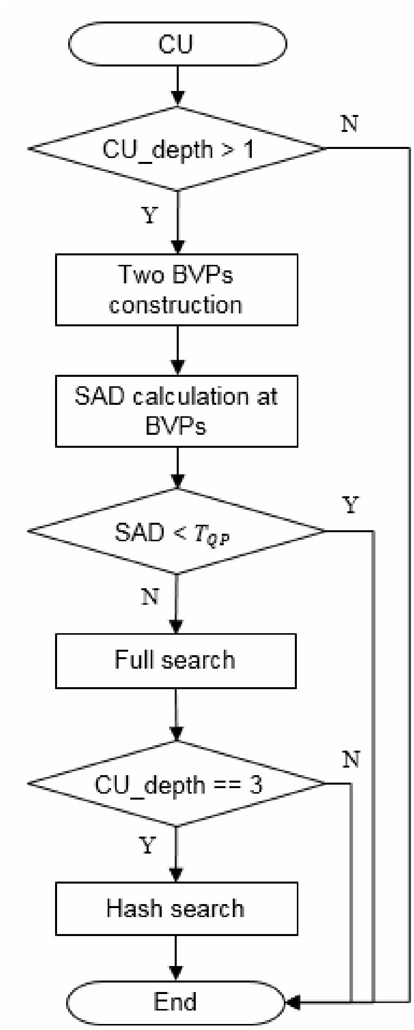


Fig. 4. IBC BV search block diagram of the proposed algorithm.

4. Performance Evaluation

The proposed algorithm was evaluated on SCM-2.0 with an AI coding configuration under the HEVC SCC CTC. Windows 7 (64-bits) OS over 3.30GHz quad core with 16GB RAM was used to evaluate the proposed algorithm. The reference software was SCM-2.0 and the result of the proposed algorithm is shown in Table 2. TS_{BVS} is the time savings of the IBC block vector search time that was calculated using Eq. (3).

$$TS_{BVS} = \frac{T_{SCM-2.0} - T_{Proposed}}{T_{SCM-2.0}} \times 100(\%) \tag{3}$$

As shown in Table 2, the time savings were more significant on the TGM and M category sequences because the selection ratio of the IBC mode is higher than CC category sequences; thus the skip mode can occur more frequently. The average time savings was 29.23% and the BD-rate was 0.41% on average. In addition, the total encoding time savings was 13.69% on average.

Table 2. BD rates and IBC BV search time saving of the proposed algorithm.

Sequence	Cat.	QP	BD-rate	TS_{BVS}
sc_flyingGraphics	TGM	22	0.90%	17.86%
		27		24.63%
		32		35.08%
		37		43.53%
sc_desktop	TGM	22	0.46%	22.23%
		27		27.94%
		32		40.07%
		37		45.20%
sc_console	TGM	22	0.92%	28.37%
		27		29.63%
		32		41.96%
		37		50.07%
MissionControlClip3	M	22	0.22%	24.87%
		27		26.09%
		32		35.80%
		37		40.01%
EBURainFruits	CC	22	-0.07%	22.30%
		27		20.25%
		32		21.21%
		37		15.45%
Kimono1	CC	22	0.01%	19.85%
		27		26.98%
		32		23.89%
		37		18.36%
Average (TGM)			0.76%	33.88%
Average (M)			0.22%	31.69%
Average (CC)			-0.03%	21.04%
Average			0.41%	29.23%

5. Conclusion

This paper proposed the early termination method for fast encoding of the HEVC SCC encoder. T_{QP} , which can be controlled by QP, was derived based on the statistical results for the early termination condition. In the proposed algorithm, the block vector search can be skipped if the SAD value at one of the blocks indicated by BVPs is less than T_{QP} . The experimental results showed that the IBC BV search time savings was 29.23% on average, and the BD rate loss was 0.41% on average.

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