Proceedings of the World Congress on Engineering and Computer Science 2014 Vol I
WCECS 2014, 22-24 October, 2014, San Francisco, USA

Fast Intra Coding by using RD Cost Candidate Elimination for High Efficiency Video Coding

Do-Kyung Lee, Miso Park and Je-Chang Jeong

***Abstract*—High Efficiency Video Coding (HEVC) is the next generation video coding standard beyond H.264/AVC. Compared with H.264/AVC, HEVC has better coding performance and video quality. However, the computational complexity of HEVC has become a serious problem caused by various prediction modes and block sizes. To solve this problem, we proposed fast algorithm for intra prediction of the HEVC standard. Using cost values, the RD cost candidate can be efficiently eliminated and the computation time of encoder is successfully decreased without noticeable BD-PSNR loss.**

***Index Terms*—Fast intra coding, HEVC, RD-cost candidate elimination, video codec**

I. Introduction

The increasing popularity of high resolution videos is caused a demand of new video compression standard. High Efficiency Video Coding (HEVC) [1], [2] is a latest international video coding standard which is established by the Joint Collaborative Team on Video Coding (JCT-VC) under the ITU-T VCEG and ISO/IEC MPEG. The HEVC adopted the block-based hybrid coding structure as H.264/AVC [3]; however it successfully achieves 50% bit-rate saving and improves subjective video quality compared to H.264/AVC. The HEVC employs new technologies which are quad-tree based coding unit (CU) decision, 35 modes for intra prediction, sample adaptive offset (SAO), discrete cosine transform (DCT) based interpolation filter for motion estimation, and etc. The basic unit of H.264/AVC standard is a macro block which is 16×16; however, the HEVC standard supports various size of blocks from 4×4 to 64×64 pixels. Coding Tree Unit (CTU) is largest coding unit which is usually set to 64×64 can be split into 4 CUs; and CU also split into 4 sub-CUs until the size of CU will be 8×8, as shown in figure 1. Also, the prediction unit (PU) for intra prediction has two modes which are 2N×2N for 16×16, 32×32 and 64×64 CUs and N×N only supported for 8×8 CUs. Using this quad-tree structure of CU, the encoder of HEVC standard can efficiently and flexibly compress high resolution sequences, for example, 4K: 3840×2160, 8K: 7680×4320, and it can be observe from figure 2. The intra prediction of the H.264/AVC has 8 and 4 prediction modes for 4×4 block and 16×16 block, respectively. On the other hand, the HEVC standard has 35 modes for 32×32, 16×16, 8×8 and 4×4, 4 modes for 64×64. Thus, the HEVC encoder can reduce spatial correlation more than H.264/AVC by using the fine intra prediction directions. However, the massive computational complexity of the HEVC standard has become an important issue; since, the encoder should calculate bits and distortion about whole block sizes, modes and coding techniques for rate-distortion optimization (RDO) process.

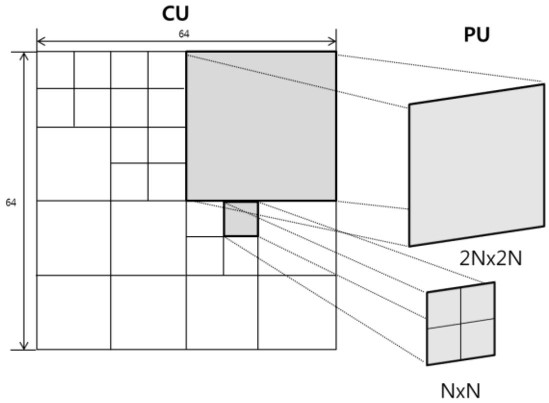

Fig. 1. Partitioning structure of CU and PU

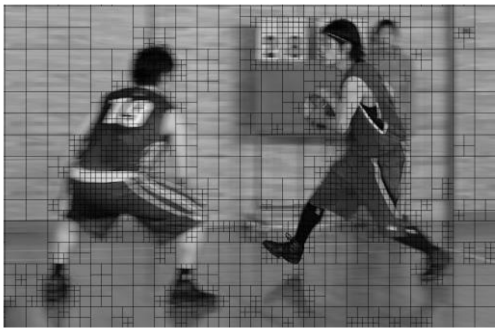

Fig. 2. CU partition of BasketballDrive test sequence

This paper is organized as follows: Section II presents the fast algorithm of the intra prediction in the HEVC standard. The details of the proposed method are introduced in Section III. Experimental results are performed in Section IV to prove the effect of the proposed algorithm. Finally, the conclusion is included in Section V.

Manuscript received July 12, 2014; revised August 16, 2014. This research was supported by the MSIP(Ministry of Science, ICT & Future Planning), Korea, under the ITRC(Information Technology Research Center) support program supervised by the NIPA(National IT Industry Promotion Agency) (NIPA-2014-H0301-14-1018).

D. Lee is with the Department of Electronics and Computer Engineering, Hanyang University, 222, Wangsimni-ro, Seongdong-gu, Seoul, Korea (e-mail: dky1006@gmail.com).

M. Park is with the Department of Electronics and Computer Engineering, Hanyang University, 222, Wangsimni-ro, Seongdong-gu, Seoul, Korea (e-mail: misosmile1128@gmail.com).

J. Jeong is with the Department of Electronics and Computer Engineering, Hanyang University, 222, Wangsimni-ro, Seongdong-gu, Seoul, Korea (corresponding author to provide phone: +82-2-2220-4369; e-mail:jjeong@hanyang.ac.kr).

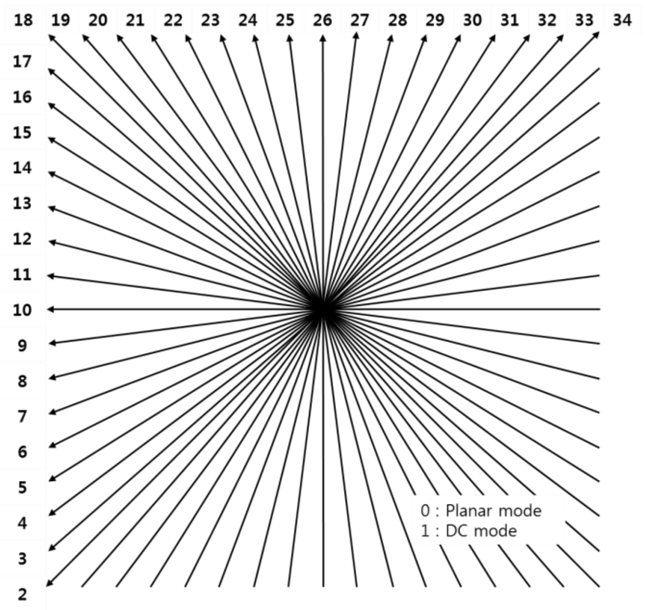

Fig. 3 The prediction modes for the HEVC intra prediction

II. Intra Prediction in the HEVC Standard

Intra prediction of video codec is adopted for removing spatial redundancies using neighboring pixels. The former video coding standard, H.264/AVC, supported 9 and 4 modes for 4x4 and 16×16 block, respectively, in case of main profile. On the other hand, the intra prediction of HEVC standard has maximum 35 prediction modes for providing fine directions are defined as figure 3. Although the coding efficiency of the HEVC standard is much enhanced compared to the H.264/AVC, the computational complexity of intra prediction is increased, as well. To compensate the demerit of the intra prediction in HEVC, many researchers proposed their techniques for reducing complexity; and among them, rough mode decision (RMD) based on the hadamard transform is accepted by JCT-VC meeting [5].

The rough mode decision which is included in HM (HEVC Test Model) software is the fast encoding algorithm using hadamard transform instead of DCT. The complexity of hadamard transform is much lower than DCT; since it needs only integer add operations. In RMD process, first, all N candidates (N = 35) are calculated with regard to the following equation:

$$C_{RMD} = HSAD + \lambda \cdot R_{\text{mode}} \quad (1)$$

where R_{mode} represents the prediction mode bits and λ is lagrangian multiplier. *HSAD* is absolute sum of hadamard transformed residual which is defined as:

$$HSAD = \sum_{i}^{W}\sum_{j}^{H}\left|\mathbf{H}(\mathbf{c}_{ij} - \mathbf{p})\mathbf{H}^{T}\right| \quad (2)$$

where $\mathbf{c}_{ij}$ denotes the current block and $\mathbf{p}$ is a predictor which is neighboring pixel responded to the prediction direction. *W* and *H* are width and height of a block, respectively. Also, **H** is defined as:

$$\mathbf{H}_{4\times4} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & -1 \end{bmatrix}, \quad (3)$$

$$\mathbf{H}_{8\times8} = \begin{bmatrix} \mathbf{H}_{4\times4} & \mathbf{H}_{4\times4} \\ \mathbf{H}_{4\times4} & \mathbf{-H}_{4\times4} \end{bmatrix}. \quad (4)$$

where $\mathbf{H}_{4\times4}$ and $\mathbf{H}_{8\times8}$ are hadamard transform kernel for 4×4 block and 8×8 block, respectively.

The best M candidates are 8 candidates for 4×4, 8×8 and 3 candidates for all other size of PUs are selected for full RD-cost calculation. Additionally, the most probable mode (MPM) is defined as a set of neighboring PU's prediction modes is supplemented to M candidates for improving coding efficiency. The full RD cost is calculated for the M candidates, the formula is as follow,

$$C_{FRD} = SSD + \lambda \cdot R_{bits} \quad (5)$$

where *SSD* is the sum of squared difference between the original block and the reconstructed block, R_{bits} represents the number of bits of coded current block. Finally, the whole procedure of Intra prediction in HEVC standard is described in figure 4.

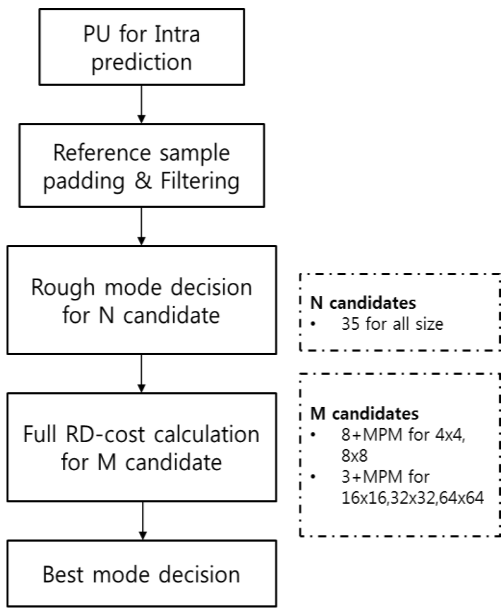

Fig. 4. The flow chart for the HEVC intra prediction

III. The Proposed Algorithm

After RMD process, M candidates for full RD calculation are sorted in ascending order in point of C_{RMD} values. Lots of final best modes are chosen by equation (5) is located at the first reordered candidate list, because C_{RMD} is estimated value of C_{FRD}.

We can observe the cumulative probability of 1, 2 and 3 candidate is over the 90%. It means most of final prediction modes are selected at these reordered positions. Even though M candidates are already reduced set among 35 modes, we can additionally reduce candidates using this concentration phenomenon with appropriate decision rule.

For speed improvement with minimum coding efficiency loss, we experiment the relationship between C_{RMD} values of M candidates and the position of the best mode in reordered candidate list. First, we calculate a variance of C_{RMD} values of M candidates with following two conditions:

- Condition 1: The index of the best mode is less than or equal to 3,
- Condition 2: The index of the best mode is bigger than 3 and less than or equal to 7.

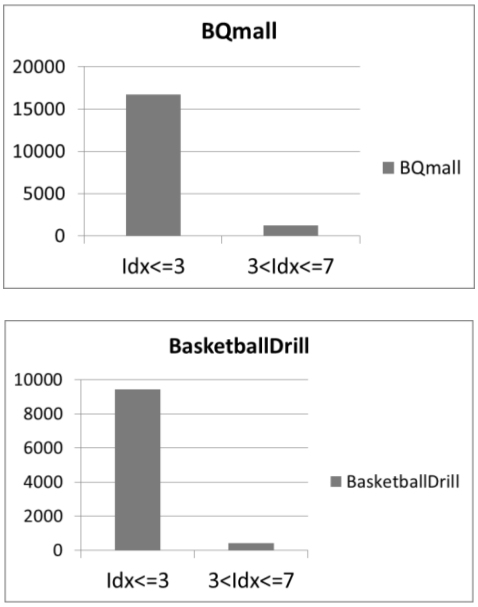

Fig. 5. The variance of C_{RMD} under condition 1 and 2

Figure 5 shows the variance under the condition 1 has much bigger than condition 2. Therefore, we may efficiently reduce candidate for full RD calculation using variance of C_{RMD} values. However, the computational complexity for evaluating variance is relatively high; it needs plenty of multiplications and additions. The variance is also not easy to predict its value for laying down criteria. We can substitute difference of first and last of reordered list for the variance as criteria; since, the C_{RMD} value of reordered list is monotonic increasing. The criterion we finally decided is shown as follows;

$$diff = \frac{rlist[8] - rlist[1]}{rlist[1]}, \qquad (6)$$

where *rlist* denotes reordered candidate list after the RMD process. The experimental results for *diff* is described in Table I.

TABLE I
EXPERIMENTAL REULTS OF *diff*

Test sequences	*rlist* 1	2	3	4	5	6	7	8
Nebuta	62	50	41	36	33	31	29	27
BQTerrace	102	83	44	35	30	27	25	22
PartyScene	61	44	34	27	23	21	20	18
BlowingBubbles	49	40	33	28	25	23	21	19
FourPeople	88	68	54	43	37	33	30	27
ChinaSpeed	117	68	56	34	31	28	26	25

We can observe the magnitude of *diff* of *rlist*[1] is relatively larger than *rlist*[8], in Table I; and, it can be suitable for using criteria for reducing candidate list. The pseudo code of proposed algorithm are defined in Table II.

TABLE II
PSEUDO CODE OF PROPOSED ALGORITHM

```
If ((rlist[8] – rlist[1])/rlist[1])>ThrFRD)
    numModesFRD = 4;
Else
    numModesFRD = 8;

(numModesFRD denotes number of modes for Full RD calculation)
```

As shown in Table II, if *diff* is larger than Thr_{FRD}, which is determined experimentally, the size of *rlist* is reduced by 4. Otherwise, it maintain the size of list for full RD calculation. For convenience, we define reduced *rlist* as *m_rlist*.

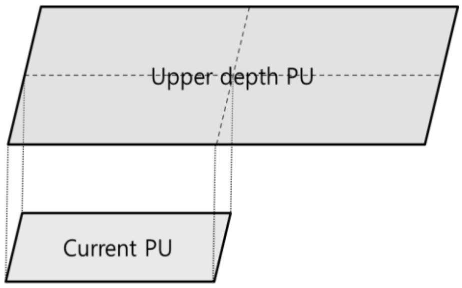

Fig. 6. The relationship between upper depth PU and current PU

Additionally, for coding efficiency and more speed improvement, we adjust *m_rist* by evaluating reliability using MPM list and the best prediction mode of upper depth PU shown in figure 6. The MPM list which is usually consisted of the optimal prediction mode of upper and left PU and the prediction mode of upper depth PU is highly correlated with the current PU's best prediction mode.

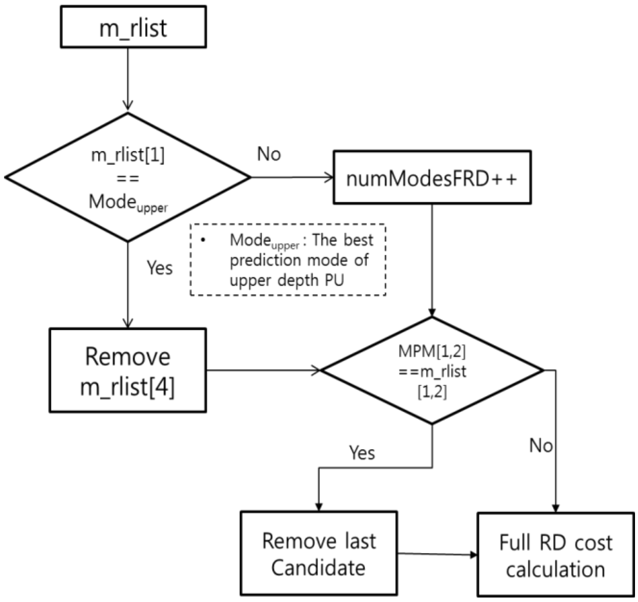

Fig. 7. The Flowchart for modifying *m_rlist*

ISBN: 978-988-19252-0-6
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

TABLE IV
EXPERIMENTAL RESULTS OF PROPOSED ALGORITHM COMPARED WITH HM 14.0

Class	Proposed algorithm (Thr_{FRD} = 0.35)			Proposed algorithm (Thr_{FRD} = 0.45)		
	BD-rate (%)	BD-PSNR (dB)	△Time (%)	BD-rate (%)	BD-PSNR (dB)	△Time (%)
A	0.0567	-0.0032	89	0.0391	-0.0022	91
B	0.0453	-0.0019	87	0.0295	-0.0012	90
C	0.0612	-0.0039	88	0.0459	-0.0027	91
D	0.0606	-0.0045	88	0.0350	-0.0026	92
E	0.0619	-0.0033	88	0.0532	-0.0028	87
F	0.2516	-0.0306	88	0.1594	-0.0194	87
Average	0.8890	-0.0078	88.2	**0.05934**	**-0.0051**	**89.9**

The proposed algorithm about additional modification for *m_rlist* is described in figure 7. First, *m_rlist*[1] is compared with $Mode_{upper}$ which is the best prediction mode of upper depth PU, if it is true, we assume that *m_rlist* is reliable. Otherwise, we supplement an additional candidate for full RD cost calculation. MPM[1] and MPM[2] is commonly equal to the optimal mode of left PU or upper PU; or they can be planar or DC mode if there are no left and upper PU. Comparing MPM modes with *m_rlist*, we can also determine whether *m_rlist* is reliable or not. If MPM and *m_rlist*[1], *m_rlist*[2] equal to each other, we decided to remove last element of *m_rlist*.

IV. Experimental Results

To evaluate the performance, the proposed algorithm is implemented in HM 14.0. We use test sequences listed in Table III. The hardware platform is Intel Core i7-4770K CPU @ 3.50 GHz and 3.50 GHz, 16.0 GB RAM with Microsoft Windows 7 64 bit operating system. For experiments, all intra (AI) configuration of the HEVC main profile is used and CTU which is the largest coding unit is 64×64 and QP = 22, 27, 32 and 37. △Time is defined as time comparison, as follows,

$$\Delta Time(\%) = \frac{Time(\text{proposed algorithm})}{Time(\text{HM14.0})}. \quad (7)$$

Table IV summarizes the experimental results of the proposed algorithm compared to HM-14.0 about two Thr_{FRD} values. As shown in Table IV, the encoding time is efficiently reduced by the proposed algorithm with negligible coding efficiency loss. The class F, which is screen contents, has relatively large coding efficiency loss than other class; because it has different image characteristics, for example, text, computer graphics and sharp edges. The experimental result have better performance when Thr_{FRD} is equal to 0.35, it has coding loss only 0.0051 dB in point of BD-PSNR.

V. Conclusions

In this paper, the fast intra prediction algorithm by RD cost candidate elimination is introduced for encoding time saving. We proposed the novel method to reduce complexity with insignificant coding loss. The proposed algorithm can eliminate full RD calculation candidates using C_{RMD} values. Using characteristics of C_{RMD} values and reordered candidate list, we can get a great performance.

References

[1] G. J. Sullivan, J.-R. Ohm, W.-J. Han, and T. Wiegand, "Overview of the high efficiency video coding (HEVC) standard," *IEEE Trans. Circuits Syst. Video Technol*., vol. 22, no. 12, pp. 1649–1668, Dec. 2012.

[2] B. Bross, W.-J. Han, G. J. Sullivan, J.-R. Ohm, and T. Wiegand, High Efficiency Video Coding (HEVC) Text Specification Draft 10, document JCTVC-L1003, ITU-T/ISO/IEC Joint Collaborative Team on Video Coding (JCT-VC), Jan. 2013.

[3] T. Wiegand et al., "Overview of the H.264/AVC video coding standard," *IEEE Trans. Circuits Syst. Video Technol*., vol. 13, no. 7, pp. 560–576, July 2003.

[4] Y. Piao, J. Min, and J. Chen, Encoder Improvement of Unified Intra Prediction, JCTVC-C207, Guangzhou, China, Oct. 2010.

[5] L. Shen, Z. Zhang and Ping An, "Fast CU size decision and mode decision algorithm for HEVC Intra Coding," *IEEE Trans. Consumer Electronics*, vol. 59, no. 1, pp207-213, April 2013.

[6] Cho, S., and Kim, M, 'Fast CU splitting and pruning for suboptimal CU partitioning in HEVC intra coding', *IEEE Trans. Circuits Syst. Video Technol.*, 2013, 23, (9), pp. 1555–1564

TABLE III
HEVC TEST SEQUENCES

Class	Sequence name	Frame count	Frame rate (fps)	Bit depth
A [2560×1600]	Traffic	150	30	8
	PeopleOnStreet	150	30	8
	Nebuta	300	60	10
	StreamLocomotive	300	60	10
B [1920×1080]	Kimono	240	24	8
	ParkScene	240	24	8
	Cactus	500	50	8
	BQTerrace	600	60	8
	BasketballDrive	500	50	8
C [832×480]	RaceHorses	300	30	8
	BQMall	600	60	8
	PartyScene	500	50	8
	BasketballDrill	500	50	8
D [416×240]	RaceHorses	300	30	8
	BQSquare	600	60	8
	BlowingBubbles	500	50	8
	BasketballPass	500	50	8
E [1280×720]	FourPeople	600	60	8
	Johnny	600	60	8
	KristenAndSara	600	60	8
F [Screen contents]	BasketballDrillText	500	50	8
	ChinaSpeed	500	30	8
	SlideEditing	300	30	8
	SlideShow	500	20	8

ISBN: 978-988-19252-0-6
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)