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A Fast Depth-Correlation Algorithm for Intra Coding in HEVC

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Abstract **—HEVC is a new video coding technique, the standard developed by JCT-VC (Joint Collaborative Team on Video Coding), that is able to support ultra high definition video coding. In HEVC, there are three types of encoding block: Coding Unit (CU), Predict Unit (PU) and Transform Unit (TU). If every block of video pixels goes through the complete mode decision process, a lot of encoding time is required, limiting its applicability in real-time applications. This paper proposes a fast algorithm that can improve the computation time of intra coding for each coding unit (CU) block. In the proposed algorithm, the depth information of coding block tree (CBT) from the previously encoded frame is used to help determine the current CU split depth and can skip many unnecessary mode computation for some cases of block decomposition. Experimental results by HM10.1 show that the proposed method can provide about 16% of time saves and maintain an acceptable video quality.**

I. INTRODUCTION

The High Efficiency Video Coding (HEVC) is established by two international organization proposals, namely ITU-T VCEG and ISO/IEC MPEG development in April 2010. The first formal edition of the HEVC is released in January 2013. HEVC is a new generation video coding standard [1] with the major goal for high definition video content compression.

Different from H.264/AVC, the HEVC adopts the quad-tree based coding structure as shown in Fig. 1, which is a recursive block splitting. The 2Nx2N and NxN are the sizes of current block and the quadruply divided one, respectively. In HEVC, there are three type of block CU, PU and TU respectively. CU is the basic coding unit whose block size is varied from 8x8 to 64x64, that can be then formed into PU and TU. In order to find the best mode, each CU block is required to undergo a rate-distortion optimization (RDO). In RDO process, the computation burden involves 35 predict modes for each possible CU block size. It is a major part of computation complexity when encoding a video. In order to reduced the computation complexity for the 35 predicted modes, HEVC adopts a Hadamard Transformed to all the intra predict modes, and then selects several modes based on different block size, as show in Table I. This process call the rough mode decision (RMD)[3]. Nevertheless, the encoded complexity is also very high.

TABLE I
NUMBER OF INTRA MODE

PU Size	Number of intra mode
64x64	3
32x32	3
16x16	3
8x8	8
4x4	8

Before, there are many fast algorithms in HEVC. Some of them focus on the 35 angular predictions to reduction prediction mode, e.g., Wei et al. [4]. They were using vertical and horizontal Sobel edge estimates for gradient calculation, and select the direction with minimum variation direction to estimate the mode direction. Motra et al. [5], exploited the co-located PU and its surrounding PU mode information to make a further reduction amount of modes. In addition, Yilong [6] proposed an algorithm on both CU and PU, in which the CU adopts neighboring CU information to determine its current CU depth while PU uses the upper layer PU mode to predict the mode. We are inspired by the above described co-located information and considering to apply for estimation of CU depth in order to reduce encoder complexity. For example, Sanghyo et al. [7] proposed to utilize Wiener filter adaptive loop filter to control the CU depth and obtained an effective reduction encoding time to an average of 8.3 %. Similarly Jong-Hyeok et al. [8] proposed a depth range selection mechanism (DRSM) for an early termination for CU split depth. The method can make a reduction 5 % of time complexity compared with JCTVC-F092[9] .

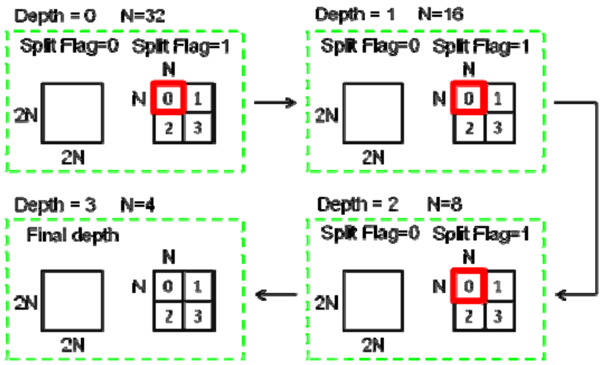

Fig 1. The illustration quad-tree coding structure.

In this paper, we proposed a method for CBT depth estimation from previously frame and current frame correlation, which is used to determine the current CU split depth within the RDO computation process. Section II illustrates the flow chart of CBT coding process in HEVC

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intra coding. Section III presents the idea of depth correlation and proves the feasibility of using correlation information. Section IV details the operation flow of the proposed method. Section V demonstrates the feasibility on computation by experiments.

II. CBT CODING PROCESS

In this section we illustrate the CBT coding process in HEVC. Each block in a CU is further split into four smaller CU blocks until the maximum depth is reached. The block split is done in a recursive manner for intra coding. It should be executed 341 times for every CU calculation in the CBT. The flow chart of CBT coding process is shown by Fig 2 and explained as follows:

Step 1. Initial settings for current split CU parameters.

Step 2. Encoding current split CU and calculate the resultant rate-distortion cost.

Step 3. Check if current CU reach to the max depth; if yes got to Step 4. Otherwise go to Step 1 to process the next split block.

Step 4. Determine the best coding split manner and decide whether further split is required.

Step 5. Check whether there are other sub-CUs split required; if yes go to Step 1 to process next CU block. Otherwise stop split.

In Fig 2, if the split depth is smaller than three, then the current block CU is split to grow the depth and make four smaller blocks until the maximum depth 3. If current depth is three, then the split is stopped and the sum of RDO costs of the four subblocks is obtained.

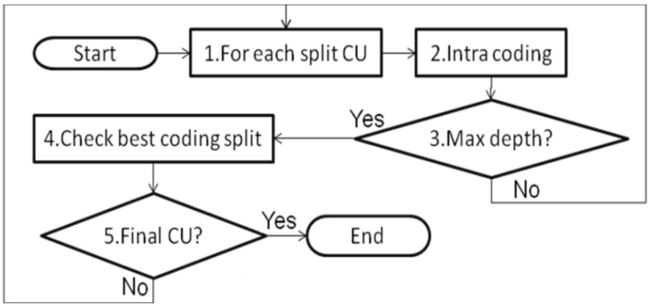


Fig 2. CBT coding process for HEVC.

III. CORRELATION ANALYZE

This paper adopts HEVC encoder module by HM10.1 [10]. In HEVC, a CU can also be split into PU and TU. Therefore, we utilize the co-located CBT information from the previous frame to reduce PU and TU calculation burden. In this section, we analyze CU depth correlation based on the observation on eight sequences, and utilizes depth information from the previous frame to reduce computation complexity. We observed the depth information distribution of CU at different sequences, and found the depth information between the consecutive frames is similar. Table II shows the observed result. The Depth difference is calculated as follows:

$$\Delta D(m,n) = \left| d_c(m,n) - d_p(m,n) \right| \qquad (1)$$

We use the 4x4 array to save the depth from the previous frame. That is used to calculate the depth difference of basic unit. In (1), (m,n) denote 4x4 block coordinate of frame, d_c and d_p represent current frame split depth value and previous frame split depth value, respectively. ΔD denotes the depth difference value.

Using (2), the value of depth difference ND, which is a number between 0 and 1, is calculated. If ΔD equals to 0 or 1 then ND is added by 1; otherwise ND is unchanged. Next the depth difference ratio of the frame is evaluated in (3).

$$for\ each\ (m,n) \begin{cases} ND = ND + 1 & if\ \Delta D(m,n) = 0,1 \\ ND = ND & Otherwise \end{cases} \qquad (2)$$

$$FDR_i = \frac{ND}{Tb} \times 100\% \qquad (3)$$

In (3) FDR represents split difference ratio of frame, i represent which frame is calculated and Tb is the total of 4x4 split blocks in this frame. Finally we calculate the depth difference from difference sequence as illustrated in (4).

$$Depth\ difference = \frac{\sum FDR_i}{Frame\ To\ Be\ Encode} \qquad (4)$$

In (4) the numerator denotes the sum of the split different ratio from each encoded frame and the denominator is the number of encoded frame in this sequence.

In Table II, the eight sequences show that up to 96% correlation of split depth of CU is revealed. This correlation can be used to decrease the number of encoded block, and achieve higher computation efficiency.

TABLE II
DEPTH CORRELATION OF FRAME

Video sequence	Resolution	Depth difference (%)
BasketballPass	416x240	97.95%
BQSquare	416x240	99.41%
Mobisode2	416x240	97.65%
Keiba	832x480	91.7%
BQMall	832x480	97.29%
PartyScen	832x480	99.1%
Vidyo1	1280x720	97.63%
BasketballDrive	1920x1080	94.88%
Average		96.95%

IV. PROPOSED METHOD

In general, the CU coding is executed recursively with splitting a lot of CU blocks. We propose a method that utilizes depth correlation property to decrease encoding time complexity. Figure 3 shows the flow chart of the proposed method when encoding current CBT. Detail description is stated as follows:

Step 1. Get the co-located CBT depth .

Step 2. Find the maximum depth MaxDepth and minimum depth MinDepth from Step 1.

Step 3. Initialize current split CU parameters.

Step 4. Check if current split depth $\text{Depth}_{(\text{Curr})}$ is between MinDepth minus one and MaxDepth plus one; if yes go to Step 5; Otherwise go to Step 7. Skip current depth encoding then process next split depth.

Step 5. Encode current split depth and calculates cost.

Step 6. Determine the best coding split manner and decide whether further split is required.

Step 7. Check whether there are other sub-CUs split required; if yes go to Step 3 to process next CU block. Otherwise stop split and process next CBT.

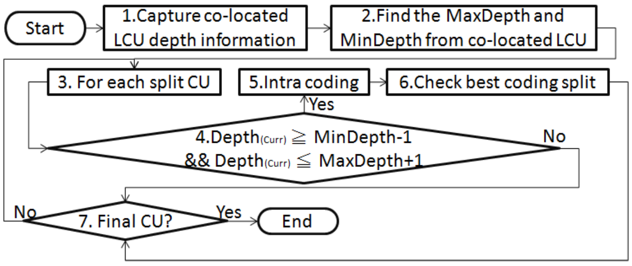


Fig 3. Fast intra coding method.

This method is exploited to skip unnecessary block decomposition computation. For example, consider the co-located CBT from previous frame as shown in Fig 4, its MaxDepth is 3 and MinDepth is 2. Then the MaxDepth for current block is added by one and the MinDepth is subtracted by one. In HEVC standard, the CU block maximum depth is 3. Hence current CBT to be encoded depth must be between 1 to 3. Therefore, we can reduce computation depth 0 and achieve improving computation complexity in this situation.

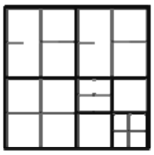


Fig 4. Co-located CBT from previously frame.

V. EXPERIMENT RESULT

Experiments are implemented based on HM10.1 [10] reference software. And the computation platform uses the Microsoft Windows 7 Professional Service Pack 1 32-bit O/S, Intel(R) Core(TM) i7-2600 3.4GHz CPU and 4 GB RAM. The experimental result as illustrated in Table III were performed on the different sequences with quantization parameters(QP) 24, 28, 32 and 36 in intra only low complexity case. Measures of coding efficiency adopt BD-Rate and BD-PSNR [11]. The time save measurement is defined in (5).

$$\text{Time Saving}(\%) = \frac{\text{Time}_{(\text{Original})} - \text{Time}_{(\text{Fast})}}{\text{Time}_{(\text{Original})}} \times 100\% \qquad (5)$$

Upon the experimental results, the proposed method can both maintain video quality and BD-Rate only increase 0.18% on average. The maximum time-savings 34.8% is occurred by Mobisode2 (832x480) sequence. In Keiba (832x480) sequence a slightly high BD-Rate is obtained, because the sequence possesses significant variety. It can be seen that PartyScene sequence come up with BD-Rate and BD-PSNR approaching zero. This means that the split depth between the frames is very similar. But in time-savings only 11.2% is obtained, because some CBT blocks are completely calculated on each sub-CU.

TABLE III
EXPERIMENT RESULT

Sequence	Resolution	BD-Rate(%)	BD-PSNR(dB)	Time-Saving(%)
BasketballPass	416x240	+0.03	0.0	10.2
Keiba	416x240	+0.3	-0.02	14.0
BQSquare	416x240	0.0	0.0	7.8
Flowervase	416x240	+0.04	0.0	15.8
Keiba	832x480	+0.85	-0.03	25.2
Mobisode2	832x480	+0.41	-0.01	34.8
BQMall	832x480	+0.05	0.0	9.3
PartyScene	832x480	0.0	0.0	11.2
Vidyo1	1280x720	+0.1	0.0	17
ParkScene	1920x1080	+0.06	0.0	15.1
Average		+0.18	0.0	16

Figs. 5 and 6 illustrate the RD curves in different resolution to compare the performance between proposed fast method and HM10.1 encoded standard difference in BasketballPass sequence and ParkScene sequences. It can be seen that the proposed fast method is almost the same PSNR on different bitrate. This means that the performance of proposed fast method is nearly identical HM10.1.

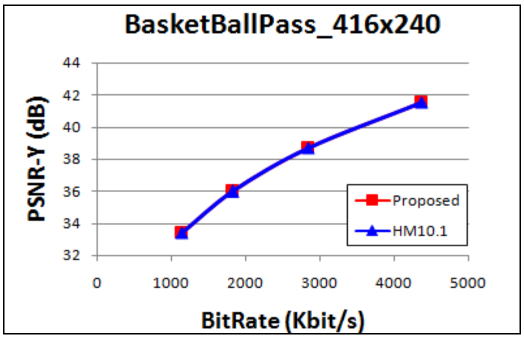


Fig 5. RD curves of proposed method and HM10.1 method for BasketballPass sequence.

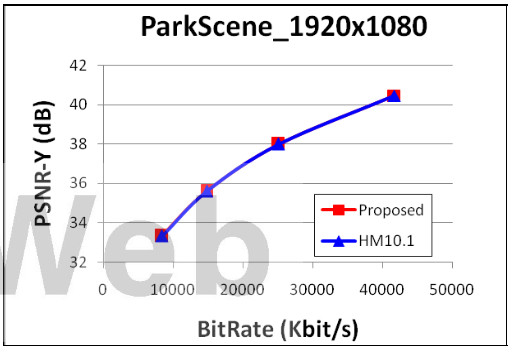
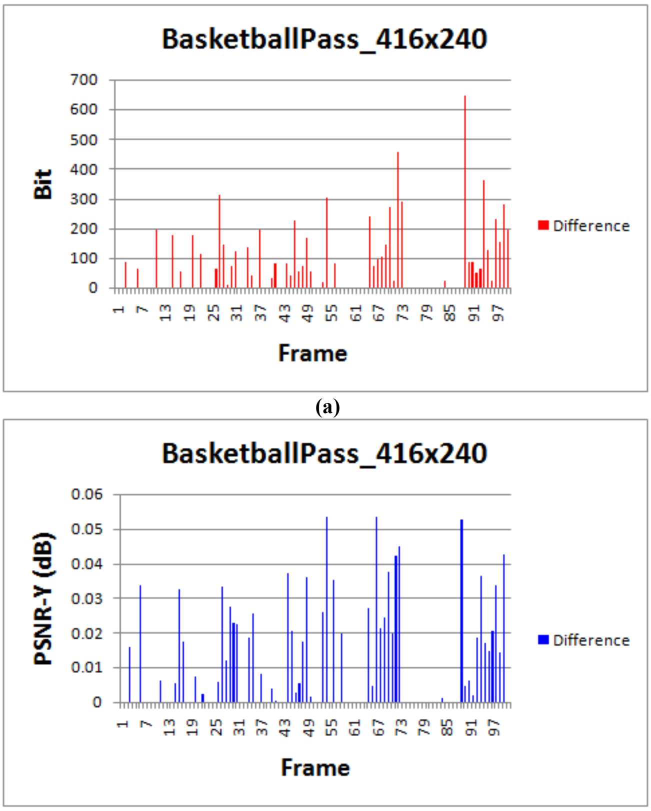


Fig. 6 RD curves of proposed method and HM10.1 method for ParkScene sequence.

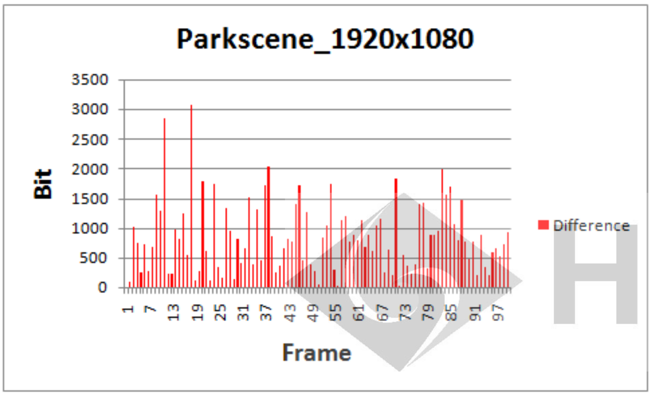
Figs. 7 and 8 show the bit-rate and PSNR of the 100 frame encoded between proposed method and HM10.1 method in QP 32 difference. Fig. 7(a) indicate that the difference of each frame in bits is not more than 700 bit. This means that the proposed method split is identical with the original method. In Fig. 7(b), the PSNR-Y is smaller than 0.06 dB in each frame. Fig. 8 demonstrates the cases on high definition sequence PakeScene. Fig. 8(a) reveals the bit differences is nearly 3000 bit and the PSNR-Y difference presented in Fig. 8(b) is very small, because there is not strong variety in this sequence. Therefore, the proposed method can provide fast encoding of intra coding and maintain the video quality.



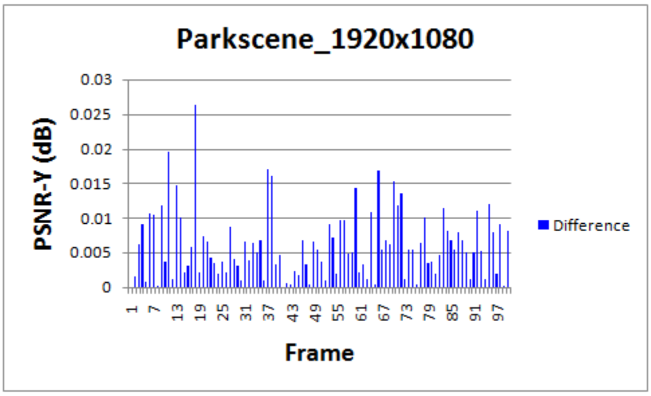
(a)

(b)

Fig 7. HM10.1 and Proposed method difference histogram: (a) the bit difference in each frame; (b) the PSNR difference in each frame.



(a)



(b)

Fig 8. HM10.1 and Proposed method difference histogram: (a) the bit difference in each frame; (b) the PSNR difference in each frame.

VI. CONCLUSION

This paper proposes a simple fast algorithm that is used to improve intra coding of CU in HEVC. The algorithm utilizes the depth correlation between previous frame and current frame to reduce computation complexity in determine the tree depth of CBT. Based on experiments, the proposed algorithm is shown to be able to offer about 16 % of time-savings under negligible loss in bit-rate.

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