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A Fast Decision Algorithm for High Efficiency Video Coding

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Abstract

Fast mode decision algorithms in video intra coding are very useful and necessary for implementing practical real-time performance of the encoder. It can reduce the computational complexity by excluding impossible modes from candidate set. Anyway, most of these algorithms may give rise to the remarkable quality degradation, especially for the all intra coding scenario. In order to improve the encoding speed while avoiding the quality loss, this paper presents a new algorithm for fast CU size decision and mode decision in HEVC intra coding. First, the size of the coding unit is pre-determined according to judging the coding unit whether has the sub-block whose depth is 3 and analyzing the depth of the adjacent CU. Then a judgment by block-DCT coefficients is made on the texture direction of image block, determining candidate mode set based on the calculated direction and the best prediction mode of the adjacent block, which can reduce the number of candidate mode, thereby reducing the amount of computation to save coding time. The experimental results show that the algorithm provides about 34.6% reduction of intra coding time compared with the latest HM13.0 with negligible loss of PSNR and a little increase of bite-rate.

Keywords*: HEVC; intra prediction; mode decision; DCT*

1. Introduction

The High Efficiency Video Coding (HEVC) standard is the latest joint video project of the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG) standardization organizations, working together in a partnership known as the Joint Collaborative Team on Video Coding (JCT-VC) [1]. HEVC is issued by the latest generation of video compression standard in January 2013. Compared with the previous standards, HEVC adopts some newly developed technologies. Under the same image quality, the coding bit rate is significantly reduced, about half of H.264/AVC, greatly improving the video compression performance. The reason why HEVC has high compression ratio is that HEVC introduced many advanced coding techniques, such as increased intra prediction directions and the flexible block structure [2]. The size of macroblock in H.264/AVC is 16 × 16, and only the size of 8 × 8 block or 4 × 4 block can use discrete cosine transform (DCT), whereas HEVC which joined the big transform block, supported the size of block from 4 × 4 to 32 × 32, and finally improved the compression efficiency. However, it comes with the tremendous encoding complexity increase [3]. Therefore, it is very useful and necessary to develop a fast algorithm for HEVC, so as to reduce the encoder complexity.

Scholars have been extensively studied fast intra mode decision for the H.264/AVC, and we only list some of them as an example [4-10]. However, these algorithms for the H.264/AVC cannot be immediately applied to HEVC, because they have quite different coding structures and prediction modes. In fact, researching the fast mode decision algorithm for HEVC is still in its initial stage, but the research has become one of hot spots in the field of video coding technology, which has broad prospects. Some fast intra

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prediction algorithms for HEVC have been proposed recently. In general, these algorithms could be divided into two categories: fast CU or PU size decision and fast intra prediction mode decision, which can be briefly summarized as follows.

1.1 Fast Coding Unit Size Decision

Shen *et al*. [11] presented an effective CU size decision method to reduce the computational complexity of the HEVC encoder. Since natural video sequences had strong spatial and temporal correlations, it determined adaptive CU depth range according to analyze the optimal depth level of the current treeblock and the co-located treeblock at the previously coded frame, and it also introduced early termination algorithms based on motion homogeneity checking, RD cost checking and skip mode checking to skip motion estimation on unnecessary CU sizes. This algorithm is implemented and reported on HM2.0, with about 61% as the maximum time saving.

A fast CU size selection method was presented in [12], where the variance value of the input image decides CU size decision. In this way, about 40% encoding time saving, as the minimum value, is compared to that of the HEVC test model HM8.0 with negligible quality degradation.

Jiang *et al*. [13] proposed a fast intra coding algorithm, detected whether the current coding unit belongs to the smooth region. According to the detection result, it can help determine how to adaptively skip the coding process of the coding unit sizes not suitable for the texture features.

Zhang *et al*. [14] proposed an algorithm about early terminating the CU and TU selection to avoid computing the RDOQ process. It had achieved considerable encoding time reduction than the reference software HM7.0, with negligible bitrate increase and PSNR loss.

A fast coding unit size decision algorithm was proposed in [15], which accomplished through the early termination for each CU with different sizes by using the corresponding RD cost thresholds, finally it achieved, on average, about 24% encoding time reduction without significant loss of BD-rate.

Shen *et al*. [16] proposed a fast CU size decision and mode decision algorithm for HEVC intra coding. Because the first-rank CU depth level is greatly content-dependent, it was ineffective to utilize a fixed CU depth range for a whole image. Hence, the algorithm could skip some particular depth levels which used less among spatially nearby CUs. It pointed out that the proposed algorithm can reduce 21% encoding time on average with negligible loss of coding efficiency.

1.2 Fast Intra Prediction Mode Decision

Zhao *et al*. [17] had presented a fast intra prediction algorithm, which is mainly studied the impact of the number of mode candidates after the RMD process in HM. The proposed arithmetic used Hadamard transform to reduce the number of candidates for doing full RDO progress. It accomplished averaged 20% and 28% encoding time saving in High Efficiency (HE) and Low Complexity (LC) test conditions on HM1.0, with a negligible loss of compression efficiency. It must point out that HE and LC test settings were used in the early stages of HEVC development, which were incorporated later then.

Zhang and Ma [18] had presented a fast intra mode decision method from macroscopic and microscopic aspects. Firstly, in order to reduce the number of inefficient intra prediction mode, the paper put forward a progressive rough mode search method based on the Hadamard cost from microcosmic layer. Next, it also proposed an algorithm which early terminate coding unit splitting if the R-D cost of the four sub-CUs were larger than the R-D cost of the current CU. It is reported that the 60% encoding time reduced with 1.0% BD-rate increase under the HEVC common test condition using a series of video sequences with different QPs.

A fast mode decision method based on the gradient direction was proposed in [19]. The gradient direction of the current prediction unit was calculated by Sobel operator and a gradient-mode column diagram was created for each CU. Based on the distribution of the column diagram that had created, the paper selected only a small part of the candidate modes for the rough mode decision and the rate-distortion optimization process. It had achieved, on average, almost 20% encoding time saving with negligible loss of coding efficiency.

The paper [20] presented a method to improve the intra mode decision according to analyze the edge direction of the current PU and further find out the correlation of intra modes, so as to reduce the computational complexity.

In the algorithm proposed by Zhang *et al*. [21], a 2:1 down sampling was applicable to the prediction residual which obtained from the sum of absolute Hadamard transformed difference (SATD). And then, a Hadamard transform was computed on down sampled prediction residual for rough mode decision. Additionally, a piecemeal exploration shortened the number of modes for Hadamard cost calculation. In order to accelerate the rate-distortion optimization process, it applied to an early termination scheme.

The remainder of this paper is organized as follows. Section II describes a brief overview of intra prediction in HEVC. Section III introduces our proposed fast decision method including fast CU size decision based on the adjacent code block and mode decision based on the calculated texture directions for HEVC intra coding. A mountain of experiments are implemented and compared in Section IV to prove the performance of the proposed algorithm. And we have a brief conclusion about our work in Section VI.

2. Overview of Intra Prediction in HEVC

A new generation of video coding standard HEVC still uses the hybrid coding scheme based on block. Compared with hybrid coding scheme in the past, it provides a highly flexible block partition structure, and the block structure includes three parts: coding unit (CU), prediction unit (PU) and transform unit (TU). It is advantageous for optimization of each unit such as the separation of the block structure. The coding unit CU is the basic unit block in intra or inter coding, which is always square, and its size from 8×8 to 64×64. The size of the coding unit is 64×64 as the largest coding unit (Largest CU). Starting from the Largest CU, each CU block can recursively split into 4 sub-blocks which have the same size until CU has been divided into 8×8 block. This process will develop a coding tree structure which consists of CU block based on adaptive content. We use the depth to represent the size of recursive CU, defined the depth of LCU is 0. When the CU is further divided into 4 sub-CUs whose size is half of the parent CU, then its depth will plus one. According to this rule, it will keep splitting into sub-CUs, when the size of CU is 8×8, that is, its depth is three. Until now, the CU will no longer continue to divide. The prediction unit PU is only at leaf nodes of quad-tree structure. For the intra case, both CU and PU are squared size with either one $2N \times 2N$ block or 4 $N \times N$ sub-blocks after further splitting, $N \in [4; 8; 16; 32]$. In addition to CU and PU, there is another transform unit with the transformation and quantization, its size cannot exceed the size of the CU. Part (a) of Figure 1 gives the recursive structure of the CU.

In addition to increasing the complexity because of the recursive block structure in HEVC, the computational complexity is further enhanced for its intra prediction directions dramatic increased. Intra prediction is an effective coding technology, removed some redundant information mainly based on the spatial correlation of the image. It has been tremendously improved in the HEVC beyond the H.264/AVC with more fine-granular predictions, where up to 35 possible intra prediction mode which including mode 0 for Planar, mode 1 for DC and others are angular modes [22], and they are illustrated in part (b) of Figure 1. However, only 9 modes are used in the H.264/AVC. As we can see, the increased number of spatial intra prediction modes will produce much higher compression efficiency, but it also brought in huge computational power using the full rate distortion (FULL RD) method for mode selection. Therefore, we must develop a fast mode decision method to reduce large amount of computation and satisfy the need of actual real-time application.

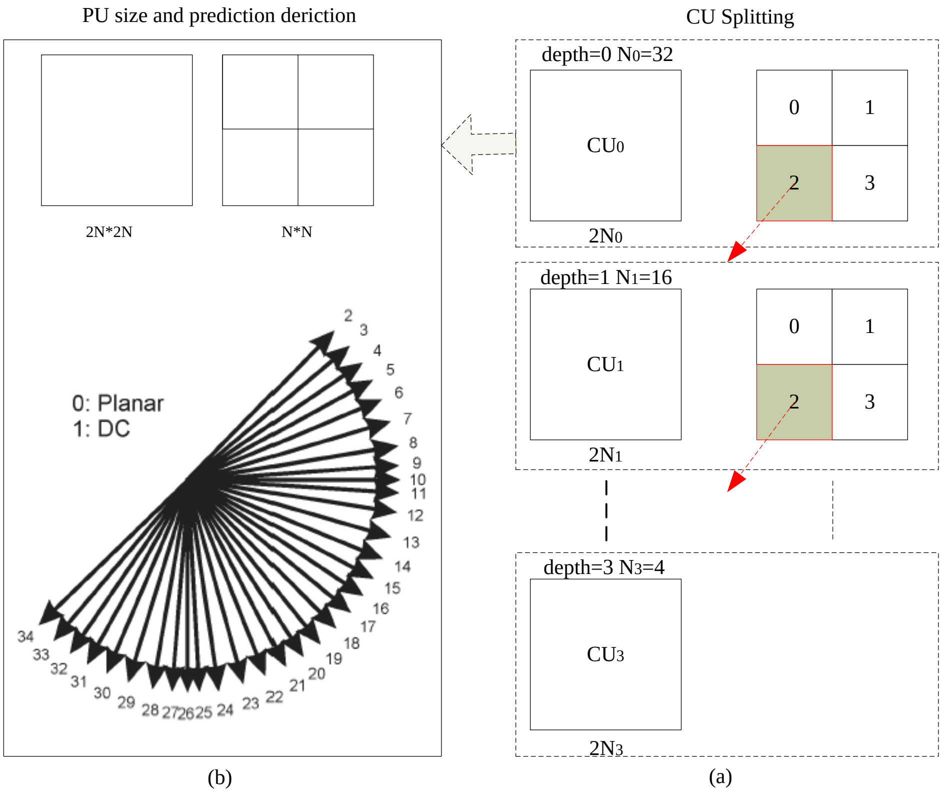


Figure 1. The Recursive Structure of the CU and Intra Prediction Directions at Each Depth Level

3. The Proposed Fast Decision Algorithm

According to the Section II in this paper, we know that spatial intra prediction goes through every possible CU size recursively, and at each CU level, it will give rise to a tremendous amount of prediction modes (*i.e.*, up to 35 for intra luma block) to derive the R-D optimal one, and the best intra prediction mode is closely related to the texture features of image in HEVC. Therefore, this paper proposes a fast decision algorithm for HEVC intra coding, which is composed of two major sub-algorithms, including fast decide CU size and prediction mode through the spatial correlation between images and the calculation of the texture angle using the DCT coefficients, so we can quickly find the best intra prediction mode of the current block, with reducing the amount of computation and saving the encoding time.

3.1 Fast CU Size Decision Based on the Adjacent Code Block

As everyone knows, natural image has strong spatial correlation. Due to the spatial correlation of adjacent pixels in the same frame, it also has a strong spatial correlation at the boundary of two adjacent LCU. And through the experiments, it is found that the depth of the sub-block which equals 3 has a great probability at the junction of two adjacent LCU. Considering relevance of the current CU and adjacent encoded CU, this paper will judge the coding unit whether has the sub-block whose depth is 3 ahead of doing intra prediction mode search for the current CU, and then decide CU size according to compare the depth of the current CU and the adjacent CU. Adjacent CU (including the left and up CU) of current frame and two adjacent LCU schematic diagram are shown in Figure 2.

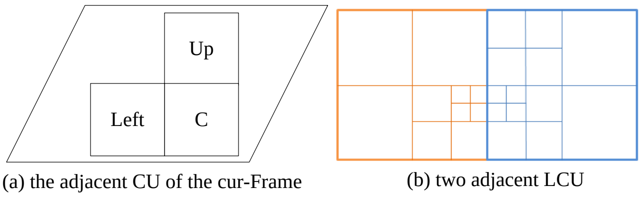


Figure 2. The Adjacent CU of Current Frame and Two Adjacent LCU

The specific evaluation process is as follows:

(1) If the size of the current unit is LCU, we firstly detect the depth of the up LCU and the left LCU. If there is at least one sub-block which depth is 3 in the adjacent LCU, we can skip to calculate rate distortion cost for the current LCU, directly splitting it into 4 sub-CUs;

(2) If the size of the current unit is 32 or 16, we detect adjacent code block of the current CU, such as the left CU and the up CU, if their depth both are bigger than the depth of the current CU, it shows that texture details in the current coding block region are more abundant. And then observe the depth of the up LCU and the left LCU, if there is the sub-block which depth is 3 in the adjacent LCU, directly splitting it into 4 sub-CUs, saving the time of encoding the current CU. Otherwise, according to the normal procedure, the current block does mode selection process.

3.2 Fast Mode Decision Based on the Calculation of the Texture Angle

HEVC provides the integer DST/DCT transform [23], the DST is only used for 4×4 TUs in transform coding of the luma prediction residual, the other is still used the integer DCT, so this paper uses the integer DCT to analyze the texture features of image [24]. The formula of IDCT is given by (1), $0 \le i, j, u, v \le 7$. The Predicting residual pixels and DCT coefficients are correspondingly represented by $f(i,j)$ and $F(u,v)$.

$$f(i,j) = \sum_{u=0}^{7}\sum_{v=0}^{7} c(u)c(v)F(u,v)\cos\frac{(2i+1)u\pi}{16}\cos\frac{(2j+1)v\pi}{16} \tag{1}$$

The partial derivative on the horizontal direction is displayed by $f_x^{'}(i,j)$

$$f_x^{'}(i,j) = \sum_{u=0}^{7}\sum_{v=0}^{7} \frac{u\pi}{8} c(u)c(v)F(u,v)\sin\frac{(2i+1)u\pi}{16}\cos\frac{(2j+1)v\pi}{16} \tag{2}$$

Definition $\overline{f_x^{'}}$ is the average value of a block's partial derivative on the horizontal direction, and the weighted values on the horizontal and vertical directions are correspondingly represented by λ_i and λ_j . $\overline{f_x^{'}}$ can be calculated according to the formula (3):

$$\overline{f_x^{'}} = \sum_{i=0}^{7}\sum_{j=0}^{7}\lambda_i\lambda_j\sum_{u=0}^{7}\sum_{v=0}^{7}\frac{u\pi}{8}c(u)c(v)F(u,v)sin\frac{(2i+1)u\pi}{16}cos\frac{(2j+1)v\pi}{16} \quad (3)$$

(4) Is adopted when the weighted value on the vertical direction $\lambda_j \equiv 1$.

$$\begin{aligned}\overline{f_x^{'}} &= \sum_{u=0}^{7}\sum_{v=0}^{7}\frac{u\pi}{8}c(u)c(v)F(u,v)\sum_{i=0}^{7}\lambda_i sin\frac{(2i+1)u\pi}{16}\sum_{j=0}^{7}cos\frac{(2j+1)v\pi}{8} \\ &= \sum_{u=0}^{7}\frac{u\pi}{8}c(u)F(u,0)\sum_{i=0}^{7}\lambda_i sin\frac{(2i+1)u\pi}{16} \\ &= \eta_1F(1,0)+\eta_2F(2,0)+\ldots\cdots+\eta_8F(8,0)\end{aligned} \quad (4)$$

In the same way, we can get the average value of a block's partial derivative on the vertical direction denoted by $\overline{f_y^{'}}$.

$$\overline{f_y^{'}} = \eta_1F(0,1)+\eta_2F(0,2)+\cdots\cdots+\eta_8F(0,8) \quad (5)$$

The direction angle of texture is represented by (6).

$$\begin{aligned}\theta &= \frac{180^\circ}{\pi}arctan\left(\frac{\overline{f_y^{'}}}{\overline{f_x^{'}}}\right) \\ &= \frac{180^\circ}{\pi}arctan\left(\frac{\eta_1F(0,1)+\eta_2F(0,2)+\cdots\cdots+\eta_8F(0,8)}{\eta_1F(1,0)+\eta_2F(2,0)+\cdots\cdots+\eta_8F(8,0)}\right)\text{其中}|\theta|<90^\circ\end{aligned} \quad (6)$$

The kernel of this algorithm utilizes the direction angle which has obtained to make out which prediction mode is the most probably be the best mode. For the 8 × 8 block, there are 33 models to identification. We defined the range of θ as [- PI /2, PI /2], and the patterns which are not in the scope are reversed to this range. Thus, it is easy to estimate the most possible intra coding mode according to the calculated direction angle θ with the formula (7). The most possible intra coding mode for 16 × 16 and 32 × 32 blocks are respectively gained according to the method.

$$Mode_{8\times8}=\begin{cases} 1,\ \ while\ \theta\in[-1.79^{\circ},1.79^{\circ}] \\ 29,\ \ while\ \theta\in\left(1.79^{\circ},3.12^{\circ}\right]\ \mathrm{or}\ 30,\ \ while\ \theta\in\left(\text{-}1.79^{\circ},\text{-}3.12^{\circ}\right] \\ 15,\ \ while\ \theta\in\left(3.12^{\circ},12.34^{\circ}\right]\ \mathrm{or}\ 16,\ \ while\ \theta\in\left(\text{-}3.12^{\circ},-12.34^{\circ}\right] \\ 28,\ \ while\ \theta\in\left(12.34^{\circ},18.97^{\circ}\right]\ \mathrm{or}\ 31,\ \ while\ \theta\in\left(\text{-}12.34^{\circ},\text{-}18.97^{\circ}\right] \\ 7,\ \ while\ \theta\in\left(18.97^{\circ},25.11^{\circ}\right]\ \mathrm{or}\ 8,\ \ while\ \theta\in\left(\text{-}18.97^{\circ},\text{-}25.11^{\circ}\right] \\ 27,\ \ while\ \theta\in\left(25.11^{\circ},30.70^{\circ}\right]\ \mathrm{or}\ 32,\ \ while\ \theta\in\left(\text{-}25.11^{\circ},\text{-}30.70^{\circ}\right] \\ 14,\ \ while\ \theta\in\left(30.70^{\circ},36.29^{\circ}\right]\ \mathrm{or}\ 17,\ \ while\ \theta\in\left(\text{-}30.70^{\circ},\text{-}36.29^{\circ}\right] \\ 26,\ \ while\ \theta\in\left(36.29^{\circ},42.18^{\circ}\right]\ \mathrm{or}\ 33,\ \ while\ \theta\in\left(\text{-}36.29^{\circ},\text{-}42.18^{\circ}\right] \\ 3,\ \ while\ \theta\in\left(42.18^{\circ},47.82^{\circ}\right]\ \mathrm{or}\ 9|6,\ \ while\ \theta\in\left(\text{-}42.18^{\circ},\text{-}47.82^{\circ}\right] \\ 18,\ \ while\ \theta\in\left(47.82^{\circ},53.71^{\circ}\right]\ \mathrm{or}\ 25,\ \ while\ \theta\in\left(\text{-}47.82^{\circ},\text{-}53.71^{\circ}\right] \\ 10,\ \ while\ \theta\in\left(53.71^{\circ},59.30^{\circ}\right]\ \mathrm{or}\ 13,\ \ while\ \theta\in\left(\text{-}53.71^{\circ},\text{-}59.30^{\circ}\right] \\ 19,\ \ while\ \theta\in\left(59.30^{\circ},64.89^{\circ}\right]\ \mathrm{or}\ 24,\ \ while\ \theta\in\left(\text{-}59.30^{\circ},\text{-}64.89^{\circ}\right] \\ 4,\ \ while\ \theta\in\left(64.89^{\circ},71.03^{\circ}\right]\ \mathrm{or}\ 5,\ \ while\ \theta\in\left(\text{-}64.89^{\circ},\text{-}71.03^{\circ}\right] \\ 20,\ \ while\ \theta\in\left(71.03^{\circ},77.66^{\circ}\right]\ \mathrm{or}\ 23,\ \ while\ \theta\in\left(\text{-}71.03^{\circ},\text{-}77.66^{\circ}\right] \\ 11,\ \ while\ \theta\in\left(77.66^{\circ},86.88^{\circ}\right]\ \mathrm{or}\ 12,\ \ while\ \theta\in\left(\text{-}77.66^{\circ},\text{-}86.88^{\circ}\right] \\ 21,\ \ while\ \theta\in\left(86.88^{\circ},88.21^{\circ}\right]\ \mathrm{or}\ 22,\ \ while\ \theta\in\left(\text{-}86.88^{\circ},\text{-}88.21^{\circ}\right] \\ 0,\ \ while\ \theta\in\left(88.21^{\circ},90^{\circ}\right] \end{cases} \tag{7}$$

3.3 Algorithm Description

Based on the above analysis, this algorithm is described as follows.

(1) If the size of the current unit is LCU, firstly detect the depth of the up LCU and the left LCU. If there is at least one sub-block which depth is 3 in the adjacent LCU, go to (3); If the size of the current unit is 32 or 16, detect adjacent code block of the current CU, such as the left CU and the up CU, if their depth both are bigger than the depth of the current CU, then observe the depth of the up LCU and the left LCU, if there is the sub-block which depth is 3 in the adjacent LCU, go to (3); otherwise, proceed with the next step;

(2) Encode the current block and then go to (4);

(3) Divide the current CU into 4 blocks, and then go to (1);

(4) DCT for the current luma block, and then calculated the θ with transform coefficients according to the formula (6);

(5) Find out the corresponding mode according to the formula (7), then add two adjacent mode and the DC mode to the candidate mode set;

(6) Judge whether the best prediction mode of the adjacent blocks is in the candidate prediction mode, if not, it is added to the candidate prediction set;

(7) Calculate the rate distortion cost of all candidate prediction modes, and choose a model with minimum cost as the optimal prediction mode;

(8) Mode decision end.

Author names and affiliations are to be centered beneath the title and printed in Times New Roman 12-point, non-boldface type. Multiple authors may be shown in a two or three-column format, with their affiliations below their respective names. Affiliations are centered below each author name, italicized, not bold. Include e-mail addresses if possible. Follow the author information by two blank lines before main text.

In order to verify the performance of the proposed fast intra prediction algorithm, it is implemented on the HEVC reference software HM13.0. The hardware configuration is Pentium (R) Dual-Core CPU with frequency 2.10GHZ; development tool is Microsoft Visual Studio 2010. Experiments are carried out for all I-frames sequences, and CABAC is used as the entropy coder. In this experiment, it used sequences recommended by JCT-VC in four resolutions which are Class A (4K×2K), B (1080p), C (WVGA), D (QWVGA), and E (720p) [25]. 100 frames of each sequence are coded to test the performance of proposed algorithm, and every frame is intra coded. The proposed algorithm is evaluated with QPs 22, 27, 32 and 37. Coding efficiency is measured with PSNR and bit rate, and computational complexity is measured with consumed coding time. We used BDPSNR (dB) to represent the changed PSNR and used BDBR(%) [26] and ΔT(%) to represent the changed bitrate and coding time in percentage, which are given by

$$BDPSNR = PSNR_{proposed} - PSNR_{HEVC} \tag{8}$$

$$\Delta T = \frac{Time_{proposed} - Time_{HEVC}}{Time_{HEVC}} \times 100\% \tag{9}$$

$$BDBR = \frac{Bitrate_{proposed} - Bitrate_{HEVC}}{Bitrate_{HEVC}} \times 100\% \tag{10}$$

The performance of the proposed algorithm is shown in Table 1. As can be seen from the table I, the proposed algorithm saves the coding time about 34.6%, whereas the peak signal to noise ratio does not change too much and the bit rate increases slightly about 1.1% than HM13.0. Therefore, the proposed algorithm can reduce the coding time and effectively improve the coding efficiency, while maintaining the video quality is basically unchanged in advance.

Table 1. Results of the Proposed Algorithm Compared to HM13.0 with Qps at 32

Class & Sequences & Picture Size			BDPSNR(dB)	BDBR(%)	ΔT(%)
A	PeopleOnStreet	2560×1600	-0.07	1.26	-36.21
	NebutaFestival	2560×1600	-0.08	1.28	-36.24
	SteamLocomotiveTrain	2560×1600	-0.09	1.30	-35.92
	zTraffic	2560×1600	-0.09	1.38	-35.83
B	ParkScene	1920×1080	-0.10	1.28	-34.37
	BasketballDrive	1920×1080	-0.09	1.31	-33.96
	BQTerrace	1920×1080	-0.10	1.03	-34.49
	Cactus	1920×1080	-0.08	1.06	-34.26
	Kimono1	1920×1080	-0.08	1.19	-34.78
C	BasketballDrill	832×480	-0.08	1.35	-32.59
	BQMall	832×480	-0.07	1.28	-32.68
	PartyScene	832×480	-0.06	1.15	-33.10
	RaceHorses	832×480	-0.08	1.02	-33.21
D	BasketballPass	416×240	-0.06	0.79	-32.02
	BQSquare	416×240	-0.05	0.86	-32.16
	BlowingBubbles	416×240	-0.08	0.98	-32.33

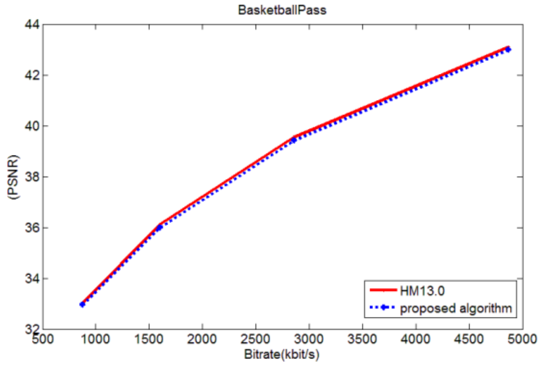
	RaceHorses	416×240	-0.09	1.06	-32.22
E	FourPeople	1280×720	-0.08	1.28	-36.56
	Johnny	1280×720	-0.12	1.36	-37.48
	vidyo1	1280×720	-0.10	1.24	-36.42
	vidyo3	1280×720	-0.10	1.20	-36.59
	vidyo4	1280×720	-0.11	1.24	-35.94
	KristenAndSara	1280×720	-0.10	1.32	-37.21
Average			-0.09	1.18	-34.63

In addition, we also conduct the simulation experiment using the optional Class F video sequences which called screen content or non-camera captured videos, where our proposed fast algorithm acquires about 35% encoding time reduction with 3% BD-rate increase, as shown in Table 2.

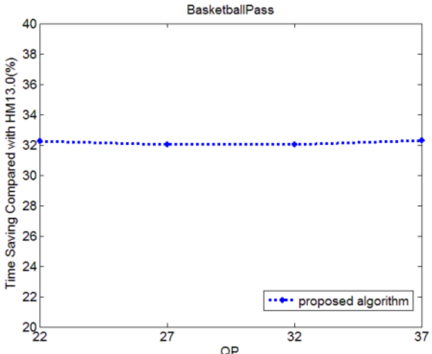
Table 2. Results of the Proposed Algorithm Compared to HM13.0 with Qps at 32 for Class F Sequences

Class & Sequences & Picture Size			BDPSNR(dB)	BDBR(%)	ΔT(%)
F	ChinaSpeed	1024×768	-0.12	2.98	-34.26
	BasketballDrillText	832×480	-0.16	2.34	-34.68
	SlideEditing	1280×720	-0.16	3.65	-33.89
	SlideShow	1280×720	-0.14	3.26	-34.55
Average			-0.15	3.06	-34.35

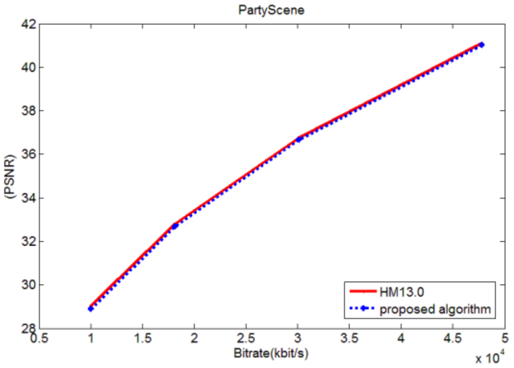
Figure 3 gives the RD Curves of the sequence of “BasketballPass”, “PartyScene”, “BQTerrace” and “PeopleOnStreet”, illustrated more detail information of the proposed fast mode decision algorithm compared to HM13.0 (QPs with 22, 27, 32, and 37). We can observe that our proposed algorithm performs almost the same coding efficiency from low to high bit-rate compared to HM13.0. Meanwhile, it can achieve consistent time saving.



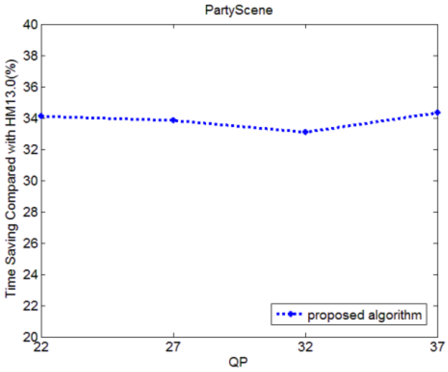
(a) RD curves of "BasketballPass"



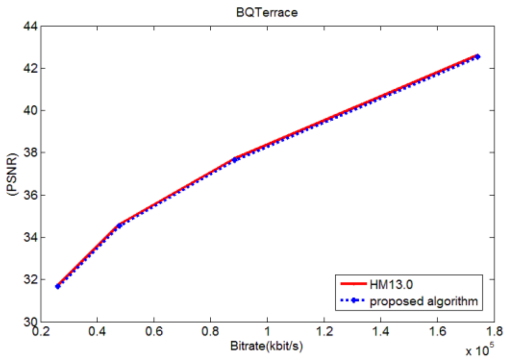
(b) Time saving curves of "BasketballPass" compared with HM13.0



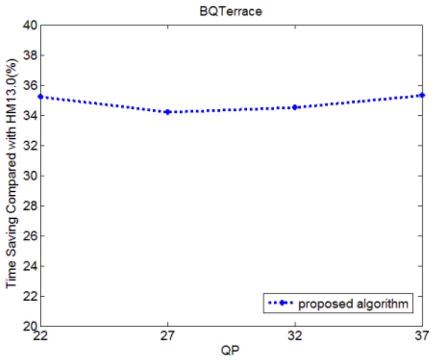
(c) RD curves of "PartyScene"



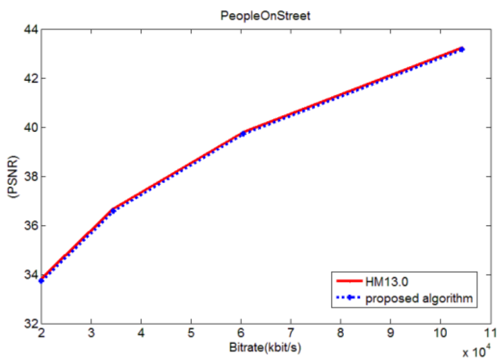
(d) Time saving curves of "PartyScene" compared with HM13.0



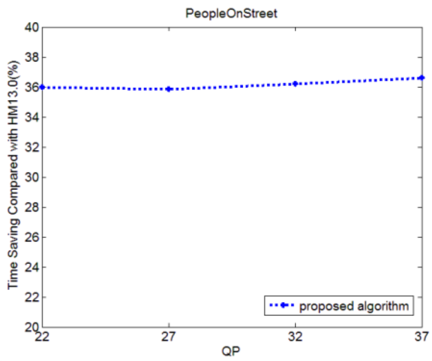
(e) RD curves of "BQTerrace"



(f) Time saving curves of "BQTerrace" compared with HM13.0



(g) RD curves of "PeopleOnStreet"



(h) Time saving curves of "PeopleOnStreet" compared with HM13.0

Figure 3. Experimental Results of Four Video Sequences ("BasketballPass", "PartyScene", "BQTerrace" and "PeopleOnStreet") under Different QPs

5. Conclusions

This paper proposed a fast mode decision algorithm for HEVC intra coding with integer transform, which was accomplished by using the coefficient matrix of discrete cosine transform and comparing the depth of the current CU and the adjacent CU to reduce the number of candidate mode set. Extensive simulations report the 34.6% encoding time reduction with 1.1% BD-rate increase using the aforementioned test condition over sequences recommended by JCT-VC compressed with different QPs, which demonstrate that the proposed algorithm can reduce the complexity of the encoder with negligible degradation of quality and BD-rate.

In addition, Class F video sequences are carried out simulation experiments in this paper. Even though the complexity reduction is retained, we see that the BD-rate raising is more than the traditional Class A to Class E video sequences, that is to say, from averaged 1.18% to 3.06% for all intra coding (cp. Table I and II). This may be caused by the difference between Class F and other classes in the video content. It requires sustained heavy effort to truly understand the Class F video and put forward fast algorithms with the reduction of computational complexity and BD-rate. It will be our next research direction.

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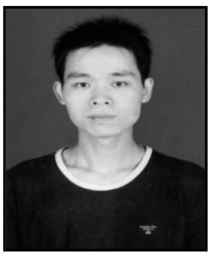

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