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Fast Intra Mode Decision for Depth Map coding in 3D-HEVC Standard

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Abstract

three dimensional- high efficiency video coding (3D-HEVC) is the expanded version of the latest video compression standard, namely high efficiency video coding (HEVC), which is used to compress 3D videos. 3D videos include texture video and depth map. Since the statistical characteristics of depth maps are different from those of texture videos, new tools have been added to the HEVC standard for intra coding. Thirty-five intra prediction modes with the recursive block partitioning structure in HEVC and the depth modeling modes improve the intra coding efficiency while increase the computational complexity. This Standard achieves the highest possible coding efficiency compared with predecessor standards, while increases the computational complexity that makes the 3D-HEVC cannot be suitable for real-time applications. In this paper, a fast intra prediction mode decision method is proposed to code depth map for 3D videos. Since the texture of video and the corresponding depth map represent the same scene, there is a high correlation between the prediction mode of texture video and its depth map. Thus, we can skip some depth map intra prediction modes rarely used in the related texture coding unit. The simulation results show that the proposed method reduces computational complexity by 23.66% compared to 3D-HEVC standard with an increase of 0.09% bit rate.

Keywords:*video compression, intra-prediction, depth-map*

1. Introduction

Three-dimensional video (3DV) depth-enhanced format has gained increasing interest recently. A depth map represents 3D scene information and is commonly used for depth Image based rendering (DIBR) [1] to support 3D television (3DTV) [2] and free viewpoint television (FTV) [3] applications. In recent years, high efficiency video coding (HEVC) based 3D video coding (3D-HEVC) technology [4, 5] is now being standardized by joint collaborative team on 3D video coding (JCT-3V) as an extension to HEVC [6, 7]. From the JCT-3V meetings, the developed coding schemes for 3D-HEVC mainly use HEVC together with exploiting temporal and interview correlation. Thus, many coding tools applied in 3D-HEVC are based on the hybrid coding scheme and highly related to HEVC.

3D-HEVC exploits depth modeling mode (DMM) [8] for a better coding of object edges in depth maps; four new intra prediction modes for depth coding are added. And conventional HEVC uses 35 different intra prediction modes for each prediction unit.

Consequently, the depth intra prediction part in 3D-HEVC, which consists of DMM and HEVC intra prediction mode, becomes the most computationally intensive part in a 3D-video depth coding system. Huge amount of depth maps data and ultrahigh computational complexity make 3D-HEVC encoder difficult not to be suitable for real-time applications. Therefore, it is necessary to develop a method that can reduce depth intra prediction complexity of 3D-HEVC with minimal loss of image quality.

The depth map represents a 3D scene information, which has the same content with similar characteristic of the texture video. Therefore, there is a high correlation among motion information from depth map and texture video. In this paper, we propose a low complexity depth compression algorithm using the correlation among motion information from depth map and texture video. The proposed algorithm consists of two stages: selection of the DMM mode for intra prediction, reduction of prediction modes based on texture of video. Experimental results illustrate that the proposed algorithm can significantly reduce the computational complexity of depth map compression while maintaining almost the same coding performance in comparison with the original 3D-HEVC encoder. In summary, we can list the main contributions of the paper as reducing the number of evaluated prediction modes which in total can provide considerable reduction in coding time and complexity while maintaining the similar coding efficiency as 3D-HEVC reference software.

The rest of the paper is organized as follows: In Section 2, we review the previous fast intra prediction mode methods for 3D-HEVC. Section 3 provides explanation on Intra coding in 3D-HEVC standard. The proposed method is presented in section 4. Simulation results and conclusions are given in Sections 5 and 6, respectively.

2. Related works

In order to reduce the complexity, Gu et al. [9] proposed a fast intra prediction scheme for depth map coding. They used a gray-correlation matrix, the prediction units (PUs) are split into different types. Therefore some unnecessary modes are avoided to be considered for some certain prediction blocks. Their method consists of two-part algorithm. In the first part, an algorithm based on a gray-correlation matrix is used to skip the DMM stage, and in the second part, the computational complexity is reduced by a reduction in angular modes. The experimental results indicate that their algorithm reduces computing time by 19.6% with a slight increase of 0.12% bit-rate on synthesized views.

Huang et al. [10] proposed a low complexity depth map intra prediction mode decision algorithm, including fast angular modes decision algorithm and early skipping DMM decision algorithm. The main idea of the proposed algorithm is to predict the current depth block intra prediction mode according to depth map texture feature and early skip DMM decision. Therefore, in this method, a low complexity depth map intra prediction mode decision algorithm is proposed that simplifies the decision process based on texture feature of depth block. This algorithm can improve 3D-HEVC coding performance without obvious quality loss. Their experimental results show that the proposed algorithm reduces coding time 38% with just an increase of 1% bit-rate.

Zhang et al. [11] proposed a fast mode decision algorithm based on variable size PU and disparity estimation (DE) to reduce 3D-HEVC computational complexity. The basic idea of their method was to utilize the correlations between depth map and motion activity in prediction mode where variable size PU and DE are needed, and only in these regions variable size PU and DE are enabled. The reported results show that the proposed

algorithm can save about 43% average computational complexity of 3D-HEVC while maintaining almost the same rate-distortion (RD) performance.
Jager [12] suggested a novel simplified intra coding mode, which works as an alternative coding path to the conventional transform-based intra coding scheme. The suggested intra coding mode yields up to 1.3% Bijontegaard delta rate (BD-rate) savings in terms of total bitrate, including texture bitrate.
Li et al. [13] detected edges from textures and then diffuse an entire block from known adjacent blocks by using Laplace equation. Their experimental results show that depth maps can be compressed more efficiently with the proposed diffusion modes, where the bit rate saving can reach 1.25% of the total depth bit rate with a constant quality of synthesized views.
The above methods are well developed to code the depth map and save time considerably. However, in this paper, by focusing on the similar information between texture video and depth map of 3D images, an algorithm is proposed that is able to accelerate the intra prediction mode process by diagnosing the HEVC or DMM prediction mode and also by reducing the number of 3D-HEVC modes is able to save time and preserve the image quality. Compared to the results of 3D-HEVC reference software, the simulation results demonstrate that the proposed method reduces computing time by 23.66% with an increase of 0.09%-bit rate.

3. Background

3D-HEVC inherits an advanced quad-tree based coding approach from HEVC, wherein a picture is divided into coding tree units (CTUs) with 64×64 size [14]. Those are equivalent to macroblocks in H.264/AVC. The CTU can then be split into four PUs, and the PU is the basic unit of region splitting used for inter or intra prediction, which allows recursive subdividing into four equally sized blocks. This process gives a content adaptive coding tree structure comprised of PU blocks that maybe as large as a treeblock or as small as 4×4 pixels [15]. Fig. 1 shows the architecture of tree structured PUs.

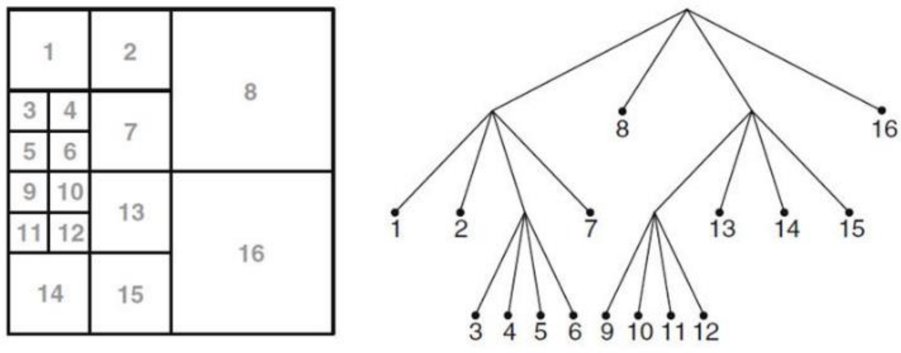

Figure 1. Architecture of tree structured PUs in 3D-HEVC.

During the intra mode decision process, 3D-HEVC uses the combination of the rough mode decision (RMD) and RD optimization (RDO) to select the best intra direction, a full RD search list is created, and N best modes in RMD (3 for 64×64, 32×32, and 16×16 PU sizes, 8 for 8×8 and 4×4 PU sizes) are selected from 35 intra prediction modes for full RD cost calculation [16]. After the selection of the first N best candidate modes based on the RMD process, all the DMM are also added to the full RD search list. However, this technique will result in extremely large computational complexity and limit the use of 3D-HEVC encoders in practical applications. Therefore, fast algorithms, which can reduce the complexity of intra decision without compromising coding efficiency, are very desirable for real-time implementation of 3D-HEVC encoders. Fig. 2 indicates 35 conventional prediction modes in 3D-HEVC including DC mode, Planar mode and 33 angular modes.

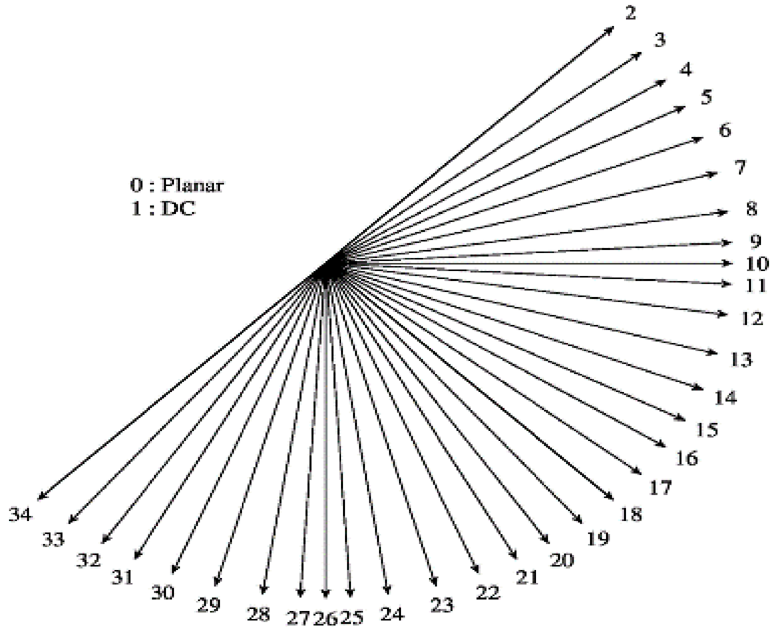

Figure 2. Intra prediction modes in 3D-HEVC.

Four DMMs including DMM1 to DMM4 are designed for a better coding of the areas with the sharp edges. Thirty-five HEVC intra prediction mode along with DMMs are employed to code the depth maps. Intra prediction modes are more efficient in the homogeneous or nearly constant regions, but they may not be effective on the edges. Therefore, the DMMs are used. Due to the very high computational complexity of DMMs, in the current version of 3D-HEVC software, two modes, namely, DMM2 and DMM3 have been removed from the four depth modeling modes. DMM1 is employed in intra and inter prediction mode, while DMM4 is only used in inter prediction mode. Since this study focuses on the intra prediction mode, DMM1 is the only DMM that is used for intra prediction. Fig. 3 indicates the flowchart of depth prediction process in 3D-HEVC.

DMM1: it is known as the explicit Wedgelet signalization [17]. The main purpose of this mode is to find the best matching Wedgelet partition at the encoder and transmit the partition information in the bit-stream. At the decoder the block is reconstructed using the transmitted partition information. The Wedgelet partition information for this mode is not predicted, but it is estimated by the Wedgelet partition. At the encoder, a search over a set of Wedgelet partitions is performed using the original depth map of the current block. During the search, the Wedgelet partition that has the minimum distortion between the original block and the approximated block is selected as the best Wedgelet partition. Then, the result is evaluated using the conventional mode decision process. Finding the best Wedgelet partition in DMM has led to an increase in computational complexity of the 3D-HEVC intra prediction unit which basically has computational complexity itself. As it can be seen in Fig. 4, in the 3D-HEVC reference software version 16.0, 47.5% of the encoding time is related to the depth map coding of the image. With a careful study, it is observed that about 13.5% of the encoding time is related to decide about finding the best Wedgelet partition in DMM.

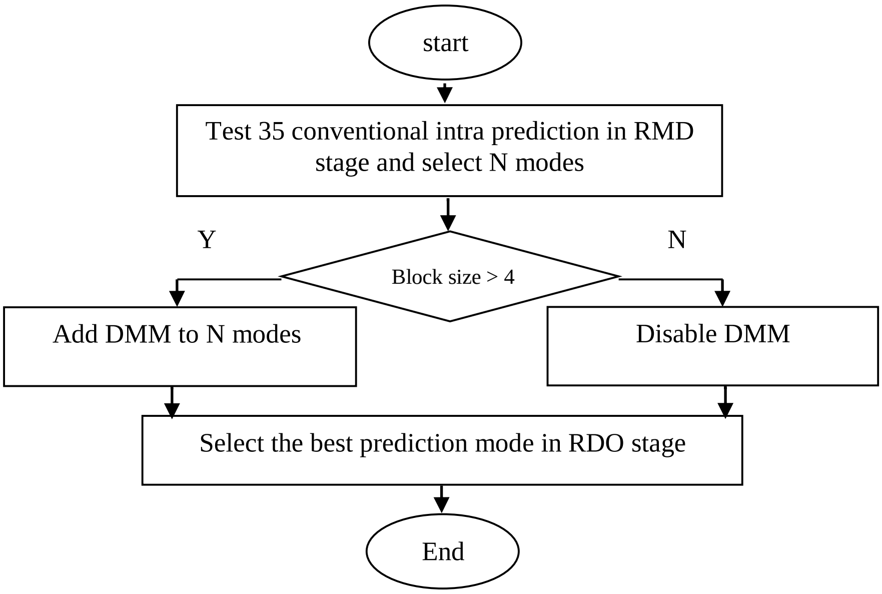

Figure 3. Flowchart of depth prediction process in 3D-HEVC [9].

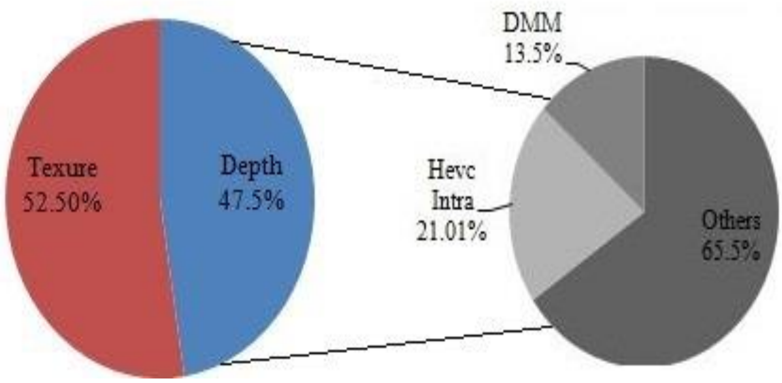

Figure 4. 3D-HEVC encoding time division in HTM [17].

4. Proposed method

Thirty-five prediction modes along with DMM1 are used for depth intra-coding in 3D videos which imposes extra computational cost. Totally, for intra-frame video coding, 36 different modes must be tested for each depth map block. Since the size of the prediction blocks can be from 64×64 to 4×4, 12276 modes must be considered for a block to get the best block size and the best prediction mode. Consequently, if a method is proposed that is able to reduce the number of intra prediction modes in depth map, the encoding time can be decreased. The results of encoding 4 videos with different resolutions are shown in Table 1. To implement the experiment, 4 different video resolutions proposed by the JCT-3V [18] have been used. The quantization parameter and other test conditions are considered in accordance with the conditions stated by the JCT-3V [18]. It also can be seen in Table 1 that in 99% of the modes, one of the 35 modes in HEVC is selected as the best prediction mode in the depth map, and DMM has very low probability of 1% to be selected as best mode.

Table 1. Statistical analysis of intra-mode distributions in depth map coding.

Sequences	QP = 34	QP = 39	QP = 42	QP = 45
Balloons	99%	99%	99%	100%
Kendo	98%	99%	98%	99%
Shark	99%	98%	99%	99%
Poznanstreet	97%	98%	99%	99%
Average	**98%**	**99%**	**99%**	**99%**

The RDO calculation costs for DMM are much higher than the calculation of 35 HEVC modes. The small probability of DMM selection suggests that the practice of deciding the best mode for all the possible intra prediction modes may have a certain limit in reducing 3D-HEVC computational complexity. If we can propose a method to decide in advance to select a DMM or HEVC directional modes, we can reduce the computational complexity to some extent. In the following, we will detail the fast decision algorithm on selecting the depth map intra prediction mode.

In the reference software, the maximum size of the prediction block is 64 × 64. The size of the prediction block can be selected from 64 × 64 to 4 × 4. The small prediction blocks are more appropriate for the areas of the image with more details and the large ones are more suitable for the areas of the image with less details. In HEVC standard, all of the block sizes are tested individually which this operation will increase the prediction time. In 3D-videos, since depth maps have large areas of nearly constant and slowly varying homogeneity regions, it is not efficient to use a full search of all prediction modes for a depth map. In fact, the small blocks are appropriate in smooth regions and the large blocks are selected for the rich texture regions. According to the experiments, the sharp object edge repeatedly occurs for a large rich region coding. On the other hand, the sharp edge of the object is rarely selected for blocks with homogeneous texture region. The results indicate that 3D-HEVC depth intra mode search should be adaptively determined based on the homogeneity checking of blocks.

Table 2 shows the correlation of prediction block size distributions among DMM. It is observed that in 90% of cases, when DMM is selected as the best intra prediction mode, the prediction block sizes are 8×8 and 4×4. It also can be seen that the percentage for a block to be coded in other sizes such 16×16 or larger is very low, about 10%.

For selecting the depth map prediction mode, the proposed fast decision algorithm is made as follows: for blocks with sizes of 8 × 8 and 4 × 4, only DMM is used, and for the other sizes only 35 directional modes are selected. In the next stage, the number of prediction modes taking part in the coding of depth map is further reduced based on correlation between texture and depth map.

The depth map represents the distance from cameras to objects, which has characteristics of the texture video. Therefore, the texture video and its related depth map represent the same scene. In general, the texture video and the depth map have similar characteristics. As shown in Fig. 5, boundaries of the depth map have similar shape with that of the texture video, and directions of object movements are the same in both texture and depth video coding. It is a high probability that prediction mode of texture is like with the depth map. Meanwhile, the prediction mode of co-located texture video affects the prediction mode of the depth map. In another word, the optimal prediction mode direction of a depth map is the similar to the prediction mode of its texture video. Thus, we can make use of the texture and depth map correlations to analyze region properties and skip unnecessary prediction modes of the depth map.

Table 2. Statistical analysis of different prediction block size distributions in DMM.

Sequences	**32 × 32**	**16 × 16**	**8 × 8**	**4 × 4**
Balloons	4.4%	7.1%	15.2%	73.3%
Kendo	4.1%	6.6%	21.1%	68.2%
Shark	4.5%	8.8%	27.3%	59.4%
Poznanstreet	1.6%	3.2%	10.5%	84.7%
Average	**3.6%**	**6.4%**	**18.5%**	**71.4%**

a ***b***

Figure 5. An example of video image and its depth map a) Image texture. b) Depth map

In the reference software of 3D-HEVC, the PUs of depth map test with 36 modes (35 conventional prediction modes along with DMM) in whole test sequence, whereas PUs of texture tested with 35 conventional prediction modes. Since the optimal depth map prediction mode is highly correlated with its co-located texture video, if 35 conventional prediction modes to be selected for evaluating, it is not efficient to test all 35 prediction modes. We can determine depth map prediction mode direction and skip other prediction modes. Based on this concept, we can force the encoder to limit the testing of the depth map at the same prediction mode direction as the prediction mode of the texture video.

With respect to the prediction mode direction of texture, a group of prediction modes including the mode with the same direction of the texture best prediction mode and its adjacent are selected to be evaluated for depth map. Each group consists of 9 modes, including one of the main modes and 8 adjacent modes, and is defined as:

$$H = \{6,7,8,9,10,11,12,13,14\}$$
$$V = \{22,23,24,25,26,27,28,29,30\}$$
$$DL = \{2,3,4,5,6,31,32,33,34\}$$
$$DR = \{13,14,15,16,17,18,19,20,21\}$$

Planar and DC modes are not directional modes; therefore, these two modes are not included in these groups. In order to provide a view about the validity of the selected prediction modes by the proposed method, extensive simulations have been conducted on a set of video sequences. Table 3 gives the accuracy of this method for the selected prediction modes. The results indicate that this method can accurately reduce unnecessary prediction modes.

Table 3. Probability that the best prediction mode in HTM16.0 is among selected modes.

Test sequence	QP=34	QP=39	QP=42	QP=45
Balloons	89%	93%	94%	97%
Kendo	93%	94%	95%	98%
Shark	91%	89%	92%	96%
Poznanstreet	92%	93%	93%	98%
Average	**91.25%**	**92.25%**	**93.5%**	**97.25%**

5. Simulation results

For implementation, 3D-HEVC reference software (HTM16.0) has been used to test the proposed method. All the simulations are defined under the common test conditions [18] defined by JCT-3V. We have tested the proposed algorithms on four sequences defined in the common test conditions with two resolutions (1024×768 and 1920×1088). The encoder configuration is as follows:

1. All frames are coded as intra.
2. For texture, quantization parameters (QPs) are set to 25, 30, 35, and 40.
3. For depth map, QPs are set to 34, 39, 42, and 45.
4. The number of frames is considered 100.
5. The minimum size of the prediction blocks is 4×4 and their maximum size is 64×64.

The coding efficiency and the coding time variations in comparison with the reference software is shown in Table 4. According to the simulation results, it can be concluded that the proposed method reduces the coding time by 23.66% due to the use of two fast mode decision algorithms, while the bit rate increases by 0.09% on average, which is due to a reduction in the number of examined modes from 36 modes to only DMM or 11 conventional prediction modes. The highest time reduction of 24.23% is related to Balloons video, with a quality of 1024 × 768, while the lowest time reduction of 23.28% is for Poznan Street video with a quality of 1920 × 1088. Also, the highest bit rate of 0.52% is related to Shark videos with a quality of 1024×768 and the lowest bit rate of 0.16% is for Poznan Street video. The simulation results for Poznan Street video are fully presented in Tables 5 and 6.
Table 5 shows the comparison between the bit rate and the image quality values in the main method and the proposed method for Poznan street video. In the proposed method, the bit rate has been slightly increased in different QP values, hence the image quality has also increased. In Table 6, Poznan Street video results for separate QPs are presented. In the proposed method, there is a time reduction of 23.28% on average for this video.
Fig. 6 indicates the comparison of Poznan street video simulation results in different QPs, in which the vertical axis shows the video compression time and the horizontal axis represents the parameter value of the compression quality. The blue color is related to the main method and the red one is for the proposed method. As it can be seen, the time reduction of the proposed algorithm is evident.

Table 4. Coding efficiency of proposed method in comparison with the reference software

Sequences	video 1	video 2	Bitrate	Time saving
Balloons	0.00%	-0.62%	-0.31%	24.23%
Kendo	0.46%	0.16%	0.31%	23.62%
Shark	0.49%	0.55%	0.52%	23.53%
Poznan_Street	0.00%	-0.32%	-0.16%	23.28%
Average	**0.23%**	**-0.05%**	**0.09%**	**23.66%**

Table 5. Poznan Street video simulation results for different QPs

Sequences	QP	Original		Proposed method	
		Bitrate(kbit/s)	**PSNR(dB)**	**Bitrate(kbit/s)**	**PSNR(dB)**
Video 0	25	21357.2000	41.2927	21400.4000	41.2958
	30	10829.0000	38.5177	10832.2000	38.5198
	35	5615.0000	36.0389	5628.8000	36.0566
	40	3111.8000	33.6379	3102.6000	33.6189
Video 1	25	21400.8000	41.2525	21407.2000	41.2449
	30	10853.0000	38.4897	10848.8000	38.5016
	35	5663.6000	36.0473	5662.2000	36.0516
	40	3097.8000	33.6267	3102.2000	33.6317
Depth 0	34	1605.0000	45.3958	1593.2000	45.2442
	39	528.6000	41.9350	550.0000	41.4275
	42	233.0000	37.9032	251.0000	37.6306
	45	121.8000	34.7679	120.4000	34.3117
Depth 1	34	1640.0000	45.1759	1615.6000	45.0615
	39	501.8000	41.1234	523.6000	41.0844
	42	227.2000	37.6461	242.2000	37.6161
	45	118.6000	34.6136	121.8000	34.8789

Table 6. Results of Poznan street video (1920×1088) for different QPs

QP	Time (s)		Time saving
	Original	**Proposed method**	
25-34	4225.529	3112.524	26.34%
30-39	4190.487	3113.112	25.71%
35-42	3763.080	2947.996	21.66%
40-45	3777.252	3055.419	19.11%
Average			**23.28%**

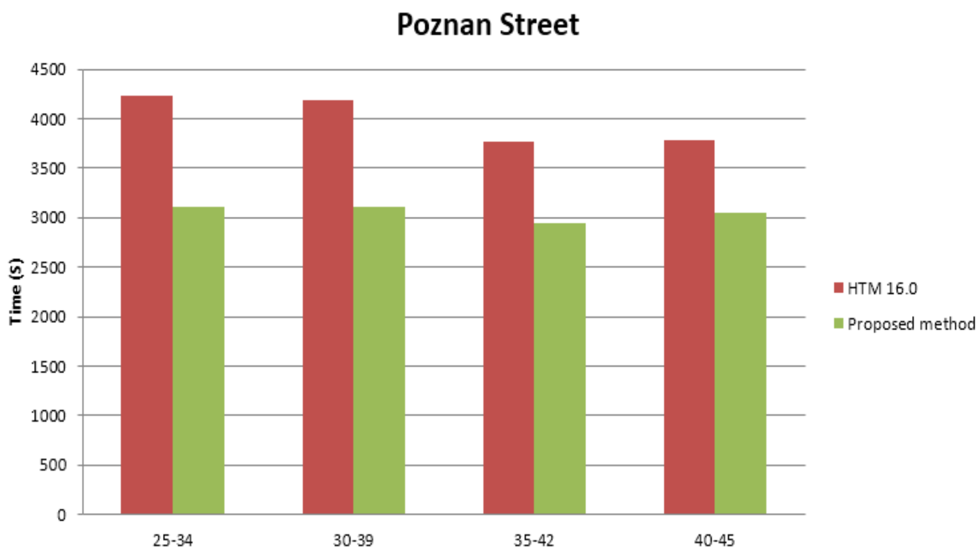

Figure 6. Simulation results of Poznan Street video (1920×1088) with different QPs

In the following, in Fig. 7, the graph of the rate-distortion of the Poznan Street video is presented in the proposed method in comparison with the HTM16.0. This curve shows the comparison between the HTM16.0 and the proposed method for Poznan Street video. Vertical and horizontal axes indicate the image quality and the bit-rate respectively. As it can be seen, due to the mode reduction, the proposed method shown by the dash line in comparison with the main method represented by the line, has a slight decrease in image quality in all QP values.

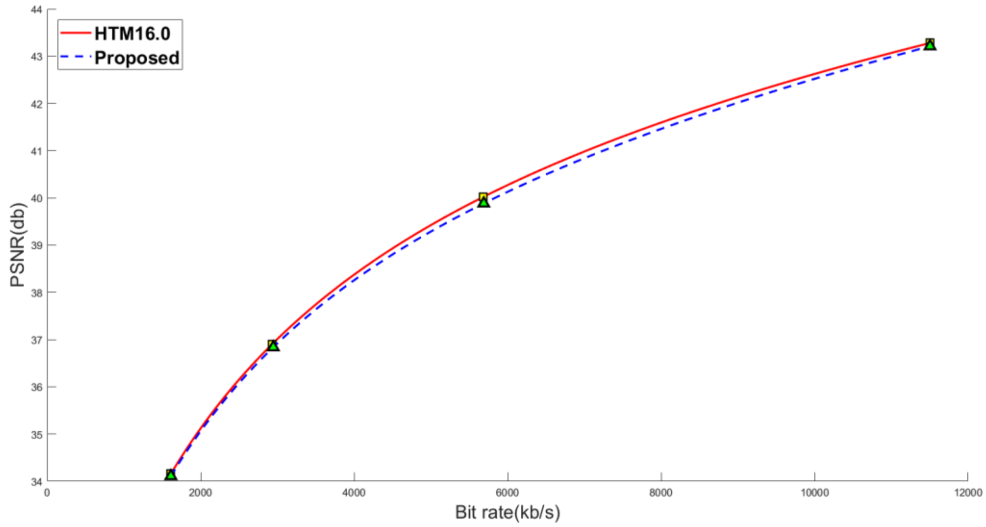

Figure 7. Results of bit-rate and PSNR in Poznan street video with different QPs

Table 7 shows the comparison of bit-rate and image quality values in the main method and the proposed method for Kendo video. In the proposed method, the bit rate has slightly increased in different QP values.

In Table 8, Kendo video simulation results are presented for different QPs in which the proposed method shows a time reduction by 23.62% on average.

Table 7. Kendo video simulation results for different QPs

		Original		Proposed method	
Sequences	**QP**	**Bitrate(kbit/s)**	**PSNR(dB)**	**Bitrate(kbit/s)**	**PSNR(dB)**
	25	4466.4000	44.9160	4462.8000	44.9187
Video 0	30	2753.2800	42.8436	2749.4400	42.8998
	35	1700.4000	40.3689	1720.3200	40.4020
	40	1095.3600	37.5714	1091.7600	37.4891
	25	4353.8400	44.8618	4354.3200	44.8665
Video 1	30	2703.8400	42.8606	2719.6800	42.9050
	35	1653.1200	40.3674	1669.9200	40.4010
	40	1043.7600	37.5833	1050.0000	37.5933
	34	651.1200	43.6166	655.6800	43.2686
	39	334.0800	38.9775	341.5200	38.3817
Depth 0	42	167.7600	35.3071	176.1600	34.9440
	45	93.6000	31.7355	97.2000	31.1777
	34	550.3200	44.6928	573.1200	44.6087
	39	315.3600	40.2040	322.0800	39.5300
	42	200.4000	36.7873	205.9200	36.7303
Depth 1	45	115.6800	33.3772	114.2400	33.5105

Fig. 8 indicates the comparison of Kendo video simulation results in different QPs, the vertical and the horizontal axes show the video compression time and the amount of compression quality parameter, respectively. The blue color represents the main method and the red one is for the proposed method. As it can be seen, the time reduction in the proposed algorithm is evident.

Fig. 9 shows the comparison between the standard method and the proposed method. The vertical and the horizontal axes represent the PSNR and the bit rate, respectively. As it can be seen, the proposed method shown by the dash line in comparison with the main method represented by the line, has a slight decrease in image quality nearly in all QP values. Table 9 shows the comparison of bit-rate and image quality values in the main method and the proposed method for Shark video. In the proposed method, the bit-rate has slightly increased in some QP values.

In Table 10, runtime simulation results of Shark video are presented for different QPs in which the proposed method shows a time reduction by 23.53% on average.

Table 8. Results of Kendo video for different QPs

QP	Time (s)		Time saving
	Original	Proposed method	
25-34	1151.351	912.215	20.77%
30-39	1229.112	922.079	24.98%
35-42	1266.519	949.255	25.05%
40-45	1390.352	1061.116	23.68%
Average			**23.62%**

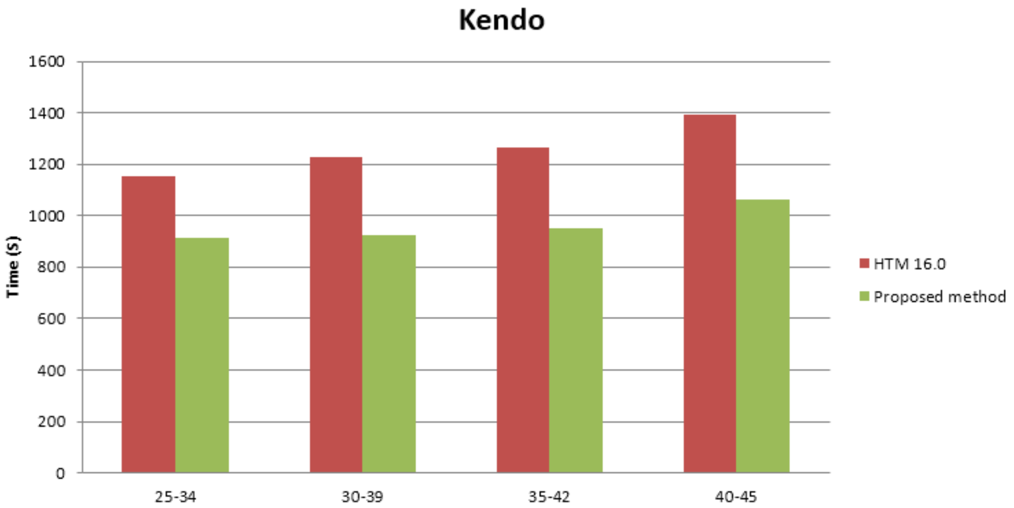

Figure 8. Simulation results of Kendo video (1024×768) with different QPs

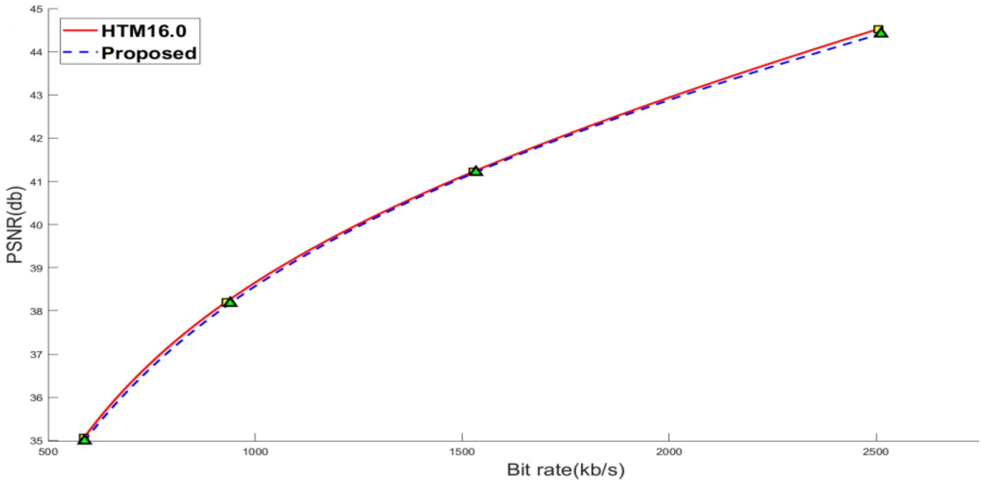

Figure 9. Results of bit-rate and PSNR in Kendo video (1024×768) with different QPs

Table 9. Shark video simulation results with different QPs

Sequences	QP	Original		Proposed method	
		Bitrate(kbit/s)	**PSNR(dB)**	**Bitrate(kbit/s)**	**PSNR(dB)**
Video 0	25	18293.5200	44.4543	18279.1200	44.4426
	30	10586.1600	41.2630	10584.4800	41.2496
	35	5723.7600	38.1314	5751.8400	38.1246
	40	2981.2800	35.2512	3007.9200	35.2533
Video 1	25	18262.0800	44.4471	18242.1600	44.4347
	30	10530.4800	41.2383	10596.7200	41.2620
	35	5665.6800	38.1230	5709.6000	38.1114
	40	2984.4000	35.2726	2994.4800	35.2581
Depth 0	34	3240.4800	40.9468	3355.9200	40.6904
	39	1585.4400	35.5831	1736.4000	35.3182
	42	709.4400	31.7344	837.6000	30.8448
	45	283.4400	28.4420	336.7200	27.1212
Depth 1	34	3302.4000	40.8563	3461.0400	40.6992
	39	1588.5600	35.6538	1767.8400	35.4547
	42	718.8000	31.9643	879.3600	31.5758
	45	284.4000	28.6614	350.1600	27.7195

Table 10. Results of Shark video for different QPs

QP	Time (s)		Time saving
	Original	**Proposed method**	
25-34	3252.255	2370.568	27.11%
30-39	3346.875	2485.724	25.73%
35-42	3308.053	2606.745	21.20%
40-45	3448.709	2755.863	20.09%
Average			**23.53%**

Fig. 10 indicates the comparison of runtime simulation results of Shark video in different QPs, the vertical and the horizontal axes show the video compression time and the parameter value of the compression quality, respectively. The blue color represents the main method and the red one is for the proposed method. As it can be seen, the time reduction in the proposed algorithm is evident.

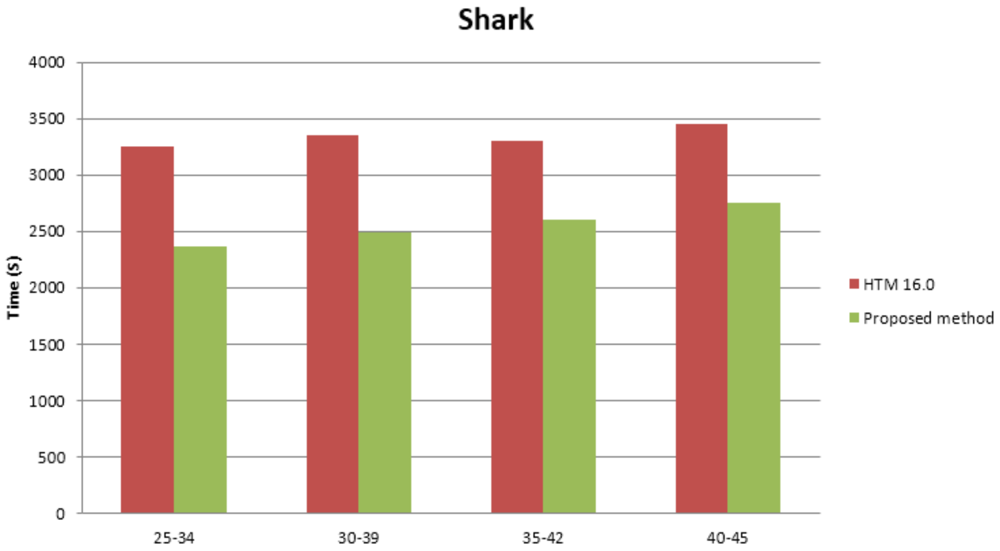

Figure 10. Simulation results of Shark video (1920×1088) with different QPs

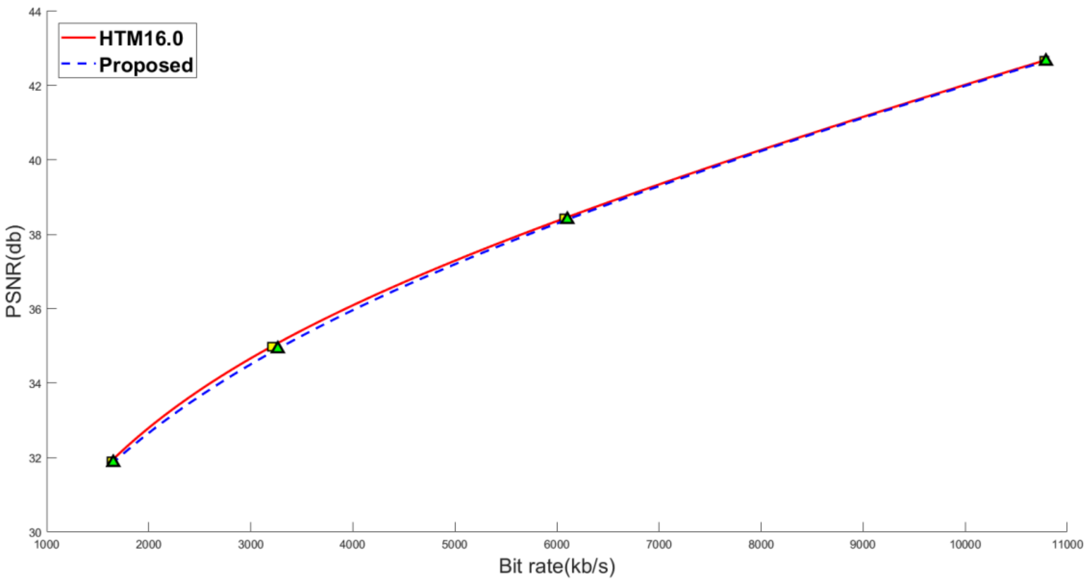

Figure 11. Results of bit-rate and PSNR in Shark video (1920×1088) with different QPs

The runtime and distortion rate graph of the proposed method compared with the HTM16.0 for the Shark video is presented in Fig. 11. The vertical and the horizontal axes indicate the image quality and the bit rate, respectively. As it can be seen, due to the mode reduction, the proposed method shown by the dash line in comparison with the main method represented by the line, has a slight decrease in image quality nearly in all QP values.

Fig. 12 shows the runtime comparison in the main method and the proposed method in all videos. The nearly one-fifth of time reduction is due to the fast decision of two algorithms for selecting the prediction mode. The results indicate that for the increase of 0.09% of bit-rate, the compression time has decreased by 23.66% on average.

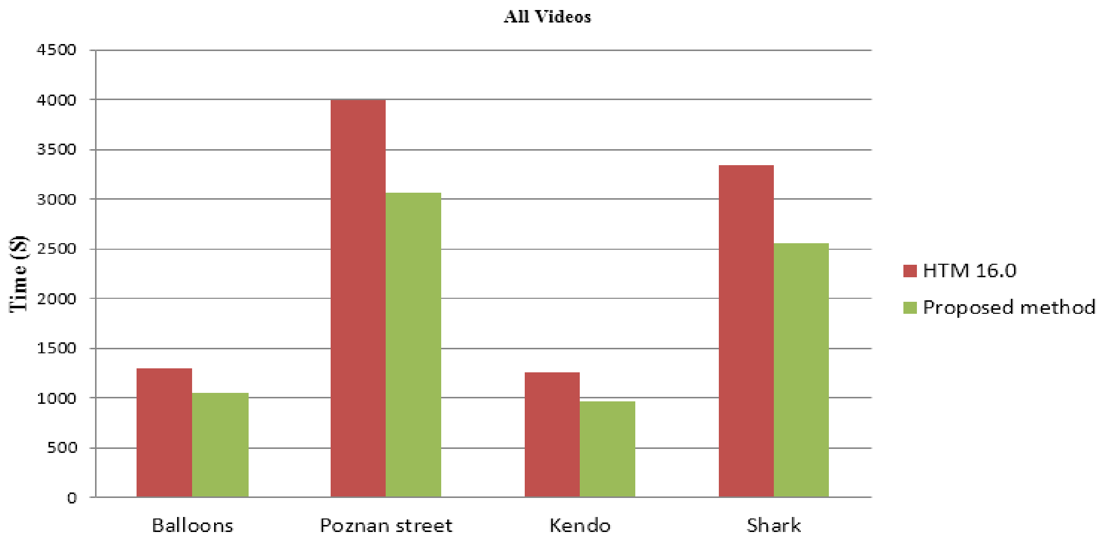

Figure 12. Simulation results of Total videos with different QPs

Table 11 shows the comparison of the proposed method with similar works. As it can be seen, the proposed method has been able to significantly reduce the coding time with the lowest bit rate. The achieved reduction in the coding time by the proposed method is higher than the other methods except Gu et al. [9]. Even though this method achieves ~4% higher reduction in the coding time compared with the proposed method, its BD-rate increases more than four times higher than the proposed method in comparison with the HEVC reference software.

Table 11. Simulation results for different methods

Methods	BD-Rate (%)	TIME (%)
Gu [9]	0.31	27.8
Zhang [19]	0.12	19.6
Huang [10]	1.00	38
Porposed method	0.09	23.66

6. Conclusions

In this paper, in the 3D-HEVC standard, a fast intra-prediction method has been presented. For the 3D-HEVC model, depth intra prediction modes include DMM prediction modes and conventional prediction modes. DMM is adapted to the specific characteristics of depth map by applying nonrectangular block partitions for approximating the signal of a depth block containing an edge. The depth map is mainly characterized by sharp object edges and large areas of nearly constant or slowly varying smooth regions. Thus, most of the prediction blocks in depth maps are smooth regions, and DMM is designed for depth map blocks with sharp edges transition which is less efficient for smooth depth map coding. So initially, an algorithm called fast mode decision was proposed to select one mode between conventional prediction modes and DMM prediction mode and then, an algorithm was proposed that if conventional prediction modes are selected in the previous stage, it further reduces the number of mods from 35 modes to 11 modes. The results show an average reduction of 23.66% in computational load and an average increase of 0.09% in bit rate which is negligible for the time reduction. Future work will focus on combining the proposed method with fast inter mode decision.

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