Deblocking Filter for Depth Videos in 3D Video Coding Extension of HEVC

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Abstract. This paper presents a modified deblocking filter for depth video coding in the 3D video coding extension of High Efficiency Video Coding (3D-HEVC). The conventional 3D video coding extension of HEVC (3D-HEVC) employs a deblocking filter and sample adaptive offset (SAO) in the loop filter in which both tools are applied to color video coding only. Nevertheless, the deblocking filter can smooth out blocking artifacts existing in coded depth videos, resulting in improving the coding efficiency. In this paper, we modify the original deblocking filter of HEVC and apply it to depth video coding. The goal is to enhance the depth video coding efficiency. The modified filter is executed when a set of conditions regarding the boundary strength are satisfied. In addition, the impulse response is altered for more smoothing between block boundaries. Experiment results show 5.2 % BD-rate reduction in depth video coding in comparison to the conventional 3D-HEVC.

Keywords: Depth video coding · Deblocking filter · HEVC

1 Introduction

The latest video coding standard, High Efficiency Video Coding (HEVC), was developed by Joint Collaborative Team on Video Coding (JCT-VC). Experts from Moving Picture Experts Group (MPEG) of ISO/IEC and Video Coding Experts Group (VCEG) of ITU-T contributed to the development. Compared to the previous coding standard, advanced video coding (AVC), HEVC is capable of doubling the compression efficiency. In 2011, the 3D video coding (3DVC) group of the MPEG issued a call for proposals (CfP) on 3D video coding technology [1]. The coding tools were required to be compatible with either AVC or HEVC. Since July 2012, the Joint Collaborative Team on 3D Video Coding Extension (JCT-3 V) has governed the standardization activities of 3D-AVC and 3D-HEVC. The development of 3D-HEVC is expected to be finalized in 2015.

In comparison to AVC, HEVC provides enhanced conventional coding tools including intra/inter prediction, transform/quantization and entropy coding [2, 3]. Sample adaptive offset (SAO) is a newly introduced tool used in the loop filter which also includes a deblocking filter. SAO is used for pixel-wise error compensation. The deblocking filter reduces blocking artifacts caused by block-based coding. In addition

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to such techniques, flexible prediction units with varying sizes are used, i.e., from 4×4 to 64×64.

Further, on top of HEVC, 3D-HEVC contains tools designed for inter-view prediction and depth video coding specifically. Redundancy between color video and its corresponding depth video is also taken into consideration. Notable tools include disparity-compensated prediction (DCP), advanced residual prediction (ARP), depth modeling modes (DMM), and depth-based block partitioning (DBBP) [4]. In this paper, we modify the deblocking filter for depth video coding. We briefly describe the procedures of the deblocking filter and present the proposed method.

2 Deblocking Filter

In HEVC, the loop filter consists of a deblocking filter and SAO. The deblocking filter is executed first, followed by SAO. These tools compensate errors to enhance the overall picture quality prior to the outputting process. Specifically, the deblocking filter is designed to reduce blocking artifacts which exhibit sudden variation of pixels at block boundaries which are caused by block-based transform coding followed by quantization [5]. Prediction of adjacent blocks also cause this problem. 3D-HEVC does not use the deblocking filter in depth video coding due to the color video-targeted design and complexity problems.

Depending on boundary strength (Bs) estimation and a number of thresholds, one of three actions is carried out: no action, normal filtering or strong filtering. Filtering is performed only when the block boundary is either a prediction unit (PU) boundary or a transform unit (TU) boundary.

2.1 Boundary Strength

8×8 sized blocks are considered when calculating Bs. Figure 1 shows an example of block boundary for deblocking filter. Figure 2 represents the Bs determining criteria. First, if at least one of the blocks is intra coded, Bs is the highest value, two. In the case that neither is intra coded,

1) One of the blocks has non-zero coded residual coefficients.
2) The blocks have different reference pictures.

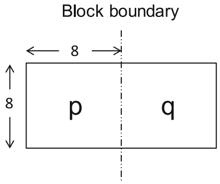


Fig. 1. Block boundary defined in the deblocking filter.

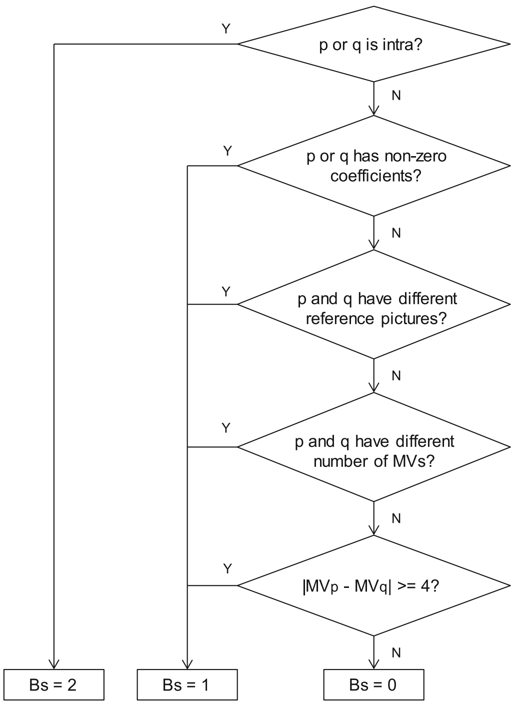


Fig. 2. Boundary strength decision.

3) They have different number of motion vectors.
4) The absolute difference of their motion vectors (MV) is greater than four.

Bs is zero if none of such conditions are satisfied. This means the block boundary is smooth with little variation. Thus, filtering is skipped in this case.

2.2 Strong/Normal Filter

The deblocking filter is executed if Bs is two or one for luma samples. For chroma samples, Bs value of two is required. Deblocking process is performed by either normal filtering or strong filtering. The type of filtering is determined by several conditions based on sample values and two defined thresholds.

3 Proposed Method

We present two modifications to the existing deblocking filter of HEVC. The modified deblocking filter is applied to depth video coding while the original deblocking filter is applied to color video coding.

3.1 Boundary Strength and Filter Type

We have analyzed the used percentages of filter types that are triggered in depth video coding. The test conditions of JCT3 V were used in this simulation [6]. Table 1 represents the results. For simple design, we adopt the most probable scenario. The strong filter is executed if Bs value is one or two. The normal filter is disabled, skipping the filter-selecting process.

Table 1. Filter type statistics.

Filter type	Percentage (%)
No action (Bs = 0)	83.9
Strong filter	14.5
Normal filter	1.6

3.2 Impulse Response

In [5], strong filtering operations is explained extensively. We denote that $p0$ and $q0$ are at the boundary and $p3$ and $q3$ are the farthest samples from the center. In this case, originally, the impulse responses for $p0$, $p1$ and $p2$ are (1 2 2 2 1) / 8, (1 1 1 1) / 4 and (2 3 1 1 1) / 8, respectively. Since depth videos show more homogeneous regions than color videos, we intensify the smoothing operation. Instead of (1 2 2 2 1) / 8 and (2 3 1 1 1) / 8, impulse responses of (1 1 1 2 1 1 1) / 8 and (1 2 1 1 1 1 1) / 8 are employed. (1 1 1 1) / 4 response remains the same.

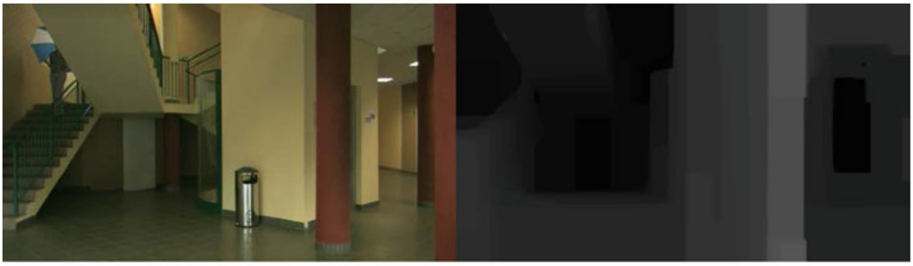
4 Experiment Results

The proposed method was implemented on 3D-HTM 13.0. Tests were conducted on four sequences that possess three views each: Poznan_Hall2 (1920×1088), Poznan_Street (1920×1088), Kendo (1024×768) and Newspaper (1024×768). These are four of the eight sequences used in JCT-3 V activities [6]. Figure 3 displays color and depth images of such test sequences. Bjontegaard delta rates (BD-rate) are measured for objective evaluation [7].

The number of coded frames is 50. Common test conditions in [5] were used. Quantization parameters (QP) are set to 25, 30, 35 and 40 for color videos. Accordingly, QPs for depth are 34, 39, 42 and 45. QPs for depth video coding are set higher since depth video coding requires less accuracy in comparison to color video coding.

Tables 2 and 3 report depth video coding performances on base view and dependent views, respectively. The base view is generally denoted by View 0 while dependent views are represented by View 1 and so on.

Tables 4 and 5 represent BD-rate results of depth and color video coding, respectively. BD-rate is employed for computing average PSNR differences between



(a) Poznan_Hall2 (1920×1088)

(a) Poznan_Street (1920×1088)

(c) Kendo (1024×768)

(d) Newspaper (1024×768)

Fig. 3. Test sequences used in the evaluation

rate-distortion curves. A negative percentage represents the amount of bit savings that can be achieved. A 5.2 % average gain 5.2 % was achieved in depth video coding. Only 0.1 % BD-rate increase was observed in color video coding. Thus, the impact on color video coding is negligible. High gains were achieved in lower QPs. This is due to the fact that blocking artifacts occur more at lower QPs.

Table 2. Depth video coding results of base view

Test sequence	QP	3D-HTM 13.0		Proposed Method	
		Bitrate (kbps)	PSNR (dB)	Bitrate (kbps)	PSNR (dB)
Poznan_Hall2	25	72.38	46.04	73.00	46.19
	30	30.17	42.55	29.69	42.74
	35	15.53	39.71	15.26	40.01
	40	8.84	37.16	8.74	37.40
Poznan _Street	25	192.16	43.76	200.79	43.59
	30	58.15	40.80	60.10	40.94
	35	23.98	37.43	24.34	37.84
	40	11.53	33.94	11.44	34.32
Kendo	25	107.66	40.23	106.84	40.56
	30	37.44	36.18	37.34	36.45
	35	16.77	33.36	16.55	33.65
	40	8.40	30.97	8.41	31.22
Newspaper	25	171.65	39.56	177.47	39.44
	30	62.43	36.18	63.68	36.39
	35	26.80	33.37	27.18	33.77
	40	12.78	30.10	12.84	30.52

Table 3. Depth video coding results of dependent views

Test sequence	QP	3D-HTM 13.0				Proposed Method			
		View 1		View 2		View 1		View 2	
		Bitrate (kbps)	PSNR (dB)	Bitrate (kbps)	PSNR (dB)	Bitrate (kbps)	PSNR (dB)	Bitrate (kbps)	PSNR (dB)
Poznan_Hall2	25	53.60	44.43	48.91	44.44	54.83	44.60	50.36	44.57
	30	20.63	41.43	18.66	41.59	20.78	41.67	19.06	41.77
	35	10.16	38.21	9.24	38.56	9.99	38.48	8.90	38.94
	40	5.44	35.50	5.14	36.16	5.29	35.67	5.14	36.41
Poznan _Street	25	117.82	42.06	136.04	41.64	124.35	42.02	141.66	41.54
	30	28.40	39.42	32.04	38.92	29.21	39.62	33.19	39.02
	35	11.21	36.39	11.22	36.23	11.10	36.70	11.74	36.57
	40	5.49	33.38	5.18	33.13	5.40	33.78	5.24	33.47
Kendo	25	88.19	37.02	113.66	35.60	89.35	37.44	114.26	35.81
	30	28.75	33.17	36.32	31.93	28.56	33.41	36.24	32.12
	35	12.69	30.65	15.72	29.31	12.54	30.79	15.71	29.62
	40	6.58	28.10	7.53	26.59	6.40	28.29	7.72	26.90
Newspaper	25	119.10	38.00	107.18	37.38	125.27	37.81	112.23	37.32
	30	44.36	34.89	35.62	34.34	45.66	35.00	36.42	34.47
	35	19.66	32.17	15.29	31.98	20.89	32.53	15.45	32.16
	40	9.10	28.94	7.63	28.95	9.49	29.41	8.03	29.64

Table 4. Depth video coding performance (BD-rate, %)

Test sequence	View 0	View 1	View 2
Poznan_Hall2	−6.4	−6.2	−6.5
Poznan_Street	−3.7	−5.9	−2.6
Kendo	−7.9	−7.3	−6.9
Newspaper	−5.2	−1.1	−2.5

Table 5. Color video coding performance (BD-rate, %)

Test sequence	View 0	View 1	View 2
Poznan_Hall2	0.0	0.0	0.3
Poznan_Street	0.0	0.2	0.0
Kendo	0.0	−0.3	0.8
Newspaper	0.0	0.5	0.0

5 Conclusion

In this paper, we presented a modified deblocking filter for depth video coding in 3D-HEVC. The conventional 3D-HEVC uses the deblocking filter for color video coding only; nevertheless, with some modifications the tool can enhance the quality of coded depth videos, increasing the practicality. The proposed method executes the strong filter if the boundary strength value is two or one. The normal filter is disabled for simplicity. In addition, the impulse response is changed to intensify the smoothing operation considering depth video characteristics. The proposed method was implemented on 3D-HTM 13.0, following the test configurations used in common test conditions employed by JCT-3 V. Experiments were conducted on four test sequences. Experiment results exhibited 5.2 % BD-rate reduction in depth video coding while maintaining the performance of color video coding. Thus, the proposed method successfully enhanced the depth video coding performance in 3D-HEVC.

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