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Lecture

Tuesday, May 22, 2012

B1L-H **High Efficiency Video Coding (HEVC)**
Time: Tuesday, May 22, 2012 (09:40 - 11:10)
Place: Room 307B
Chair(s): Wan-Chi Siu, *Hong Kong Polytechnic University*
Chia-Wen Lin, *National Tsing Hua University*

09:40
B1L-H.1 **Counter Based Adaptation for CAVLC in HEVC**
Bin Li, Houqiang Li, *University of Science and Technology of China;*
Jizheng Xu, *Microsoft Research Asia*

09:58
B1L-H.2 **Complexity Analysis of Next-Generation HEVC Decoder**
Marko Viitanen, Jarno Vanne, Timo D. Hämäläinen, Moncef Gabbouj, *Tampere University of Technology*;
Jani Lainema, *Nokia Corporation*

10:16
B1L-H.3 **Compression Performance of High Efficiency Video Coding (HEVC) Working Draft 4**
Bin Li, *University of Science and Technology of China*;
Gary J. Sullivan, Jizheng Xu, *Microsoft Corporation and Microsoft Research*

10:34
B1L-H.4 **Scalability Support in HEVC**
Danny Hong, Wonkap Jang, Jill Boyce, Adeel Abbas, *Vidyo, Inc.*

10:52
B1L-H.5 **Improved Near-Lossless HEVC Codec for Depth Map Based on Statistical Analysis of Residual Data**
Jung-Ah Choi, Yo-Sung Ho, *Gwangju Institute of Science and Technology*

Improved Near-lossless HEVC Codec for Depth Map based on Statistical Analysis of Residual Data

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Abstract—**A depth map represents three-dimensional (3D) data and is used for depth image-based rendering (DIBR) to synthesize virtual views. Since quality of the rendering view depends on that of the depth map, we should encode the depth map by maintaining the original quality. However, lossless depth coding requires a large amount of bits to carry the encoded depth map over the network. Thus, in this paper, we encode the depth map using high efficiency video coding (HEVC) near-lossless coding considering trade-off between the high quality and the bit saving. In addition, in order to improve the compression efficiency of HEVC near-lossless coding, we use large coefficients clipping and limited codeword lengh Golomb-Rice (GR) code, considering the statistical analysis of residual data. Experimental results show that the proposed method provides approximately 16.59% and 0.54% bit savings compared to HEVC lossless depth coding and HEVC near-lossless depth map coding, without the significant degradation of the synthesized view quality.**

I. INTRODUCTION

Recently, various multimedia services have become available and the user's demand for the next-generation multimedia systems is growing rapidly. Among various multimedia services, three-dimensional video (3DV) and free viewpoint video (FVV) technologies are recognized as one of the promising next-generation multimedia services and many related researches are emerging [1].

The main difficulty of 3DV and FVV systems appears to be the large bandwidth requirements associated with the transport of multi-view video. Therefore, instead of using a large number of views, a multi-view video plus depth (MVD) system [2] is proposed. Depth data provides information on 3D scene geometry and help in virtual intermediate view generation.

The virtual view is rendered by depth image-based rendering (DIBR) and quality of the virtual view depends highly on that of the depth map. Thus, efficient depth coding is important to realize the realistic and immersive 3D scene. Many researches on depth map coding and bit-rate allocation for texture and depth data relying on quality of an intermediate synthesized view are performed.

In the MVD system, depth maps are encoded by lossy coding. However, we should ensure the preservation of essential data in the depth map. Indeed, it has shown that coding artifacts on depth data can dramatically influence quality of the synthesized view.

Recently, lossless depth map coding using H.264/AVC is proposed [3]. It maintains quality of the original depth map, but it requires a lot of bit-rate. In general, bit rate for the depth map should be between 10% and 20% of total bit-rate for texture data to guarantee efficiency of DIBR.

In this paper, we encode the depth map using a newly developed high efficiency video coding (HEVC) standard [4] in near-lossless mode. HEVC near-lossless coding can achieve both high quality and bit saving. However, the HEVC standard cannot provide the optimum coding performance for near-lossless depth map coding, since it is designed for lossy texture coding. Thus, we tried to improve the depth map coding performance based on statistical analysis of residual data in HEVC near-lossless coding.

II. PROPOSED HEVC NEAR-LOSSLESS DEPTH CODING

Since quality of synthesized virtual views highly depends on quality of the depth map, efficient depth coding is crucial to realize the high quality 3D scene. However, if we encode the depth map under lossless coding mode, we only obtain about 2 times compression efficiency, compared to original data. If we use lossy coding to reduce the bit-rate, we should bear the quality degradation of the virtual view.

A new category of the compression technique called near-lossless coding is evolving. Near-lossless coding guarantees that differential pixel values between original and reconstructed pixels cannot exceed a specified upper limit [5]. Thus, near-lossless coding is appropriate to compress important data such as the depth map, considering both high quality and bit saving.

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Recently, the transform without quantization is proposed as near-lossless codec [6]. Instead of it, we use low quantization parameter (QP) to construct near-lossless codec easily [7]. In H.264/AVC, we define QP below 20 as near-lossless coding, considering subjective quality of the decoded image. Before anything else, we have to define the range of QP for HEVC near-lossless coding.

For lossless coding, transform and quantization modules are removed. The QP range for lossy coding can be found in common test conditions for HEVC-based 3D video coding [8]. As shown in Table I, QP values for the texture video and QP values for the depth video are paired. Here, QP_T and QP_D represent QP values for texture and depth videos, respectively. Note that the range of QP values for the depth video is from 34 to 51.

TABLE I. QUANTIZATION PARAMETER PAIRS FOR LOSSY CODING

QP_T	25	26	27	28	29	30	31	32	33	34	35	36	37	38
QP_D	34	35	36	37	38	39	40	41	41	42	42	43	43	44
QP_T	39	40	41	42	43	44	45	46	47	48	49	50	51	-
QP_D	44	45	45	46	47	47	48	49	50	50	50	50	51	-

To find the valid QP range for near-lossless coding, we checked quality and bit-rate results using various QP values. We encoded the *Breakdancers* (1024×768, 15fps) sequence using lossless coding and lossy coding with QP values from 0 to 36. The results are represented in Fig. 1 below. In Fig. 1, each dot on the curve signifies each QP value.

The bit-rate after lossless coding is 6649.32 kbps and we marked in Fig. 1. This value becomes the lower bound of the valid near-lossless region. We determined the upper bound is 33, since QP values over 34 are used in lossy coding. In other words, the valid QP range for near-lossless coding is from 4 to 33. Note that quality of the decoded image in near-lossless coding is quite high with a minimum of about 44dB.

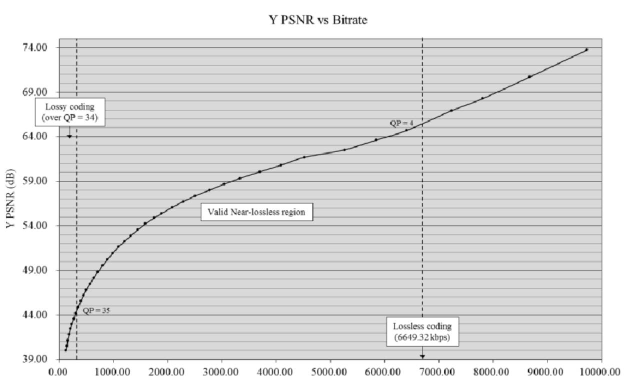

Figure 1. Valid QP range decision for near-lossless coding.

III. PROPOSED LEVEL CODING METHOD BASED ON STATISTICAL ANALYSIS OF RESIDUAL DATA

For the absolute value of the quantized transform coefficient minus 3 (*coeff_abs_level_minus3*) in the current HEVC standard, the truncated Golomb-Rice (GR) code with the Rice parameter k is applied [9]. In order to reduce the complexity of the unary/kth order Exp-Golomb (UEGk) code in H.264/AVC, TGRk code is proposed. The complexity problem of UEGk in H.264/AVC is caused by adaptive context modeling. Using the truncated GR code, we do not need any context modeling process.

The truncated GR code is constructed as follows. Given a particular Rice parameter *k*, an absolute transform coefficient *n* to be coded is consists of prefix part *p* and a remainder part *r*. The prefix is coded using a unary code and the remainder is coded using a truncated binary representation. The truncated GR code has four different codes with a parameter k = 0 to k =3. That is, the maximum of the Rice parameter is chosen to be equal to 3.

$$p = \left\lfloor \frac{n}{2^k} \right\rfloor \quad where\ r = n - p \cdot 2^k \tag{1}$$

The initial value of the Rice parameter is always 0. Truncated GR binarization is characterized by the adaptive cutoff value according to the Rice parameter *k*. As example, when the k is equal to 2, the cutoff value is 42. Thus, *coeff_abs_level_minus3* from 0 to 42, truncated Rice code is used. From 43, all lower bins are filled with 1 as a prefix part followed by k bit remainder, and the order 0th Exp-Golomb (EG0) code is used as a suffix part. The cutoff value for each Rice parameter is shown in Table II.

TABLE II. CUTOFF VALUE ACCORDING TO THE RICE PARAMETER

Rice Parameter	Cutoff Value
0	7
1	20
2	42
3	70

A. Large Coefficients Clipping

Generally, the depth image is simpler than the color image. It is likely to be predicted well, and the magnitude of level after quantization is relatively small. Figure 2 shows the probability distribution of *coeff_abs_level_minus3* for the depth image. We encoded various depth sequences in near-lossless environments and checked the probability distribution of residual data according to level information.

As shown in Fig. 2, most levels are small values. Levels from 0 to 15 occupy about 98.5 % of all levels. There are a few levels of small value; however, large bits are required to encode these levels using the GR code. Thus, in the proposed method, we clip off large coefficients over 15 to prevent the bit-rate increase.

It drives additional error in the decoded image. However, the amount of additional error is not very large because the amount of clipped coefficients is not so large either. As a result, total error after clipping can be described by Eq. (2). Here, e_n and e_c stand for near-lossless coding error and clipping error, respectively. Near-lossless coding error is comprised of the sum of transform and quantization error.

$$e = e_n + e_c = (e_t + e_q) + e_c \tag{2}$$

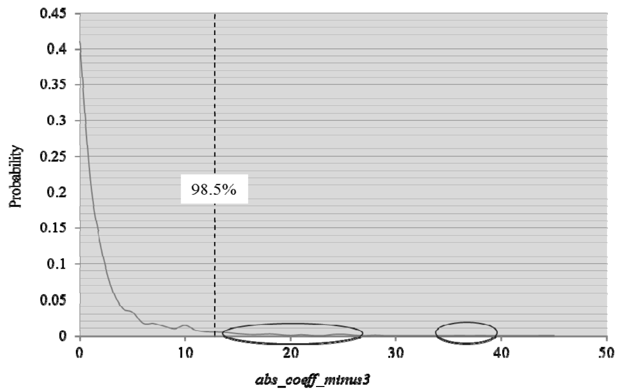

Figure 2. The probability distribution of residual data after near-lossless depth coding according to the magnitude of level information.

B. Modified GR Code with the Limited Codeword Length

After large coefficients clipping, the magnitude of *coeff_abs_level_minus3* is limited from 0 to 15. Thus, we use the modified GR code with the limited codeword length [10]. All codewords contain codewords not longer than 8 bits.

The used code is shown in Table III. The codewords above the underlined one in Table III are identical to equivalent codewords in the GR code. The update method for the order of GR code is same as that of the conventional GR code in HEVC.

TABLE III. THE MODIFIED GR CODE (CODEWORD LENGTH = 8 BITS)

Sample	Code			
	k = 0	**k = 1**	**k = 2**	**k = 3**
0	0·	0·0	0·00	0·000
1	10·	0·1	0·01	0·001
2	110·	10·0	0·10	0·010
3	1110·	10·1	0·11	0·011
4	1111·000	110·0	10·00	0·100
5	1111·001	110·1	10·01	0·101
6	1111·010	1110·0	10·10	0·110
7	1111·011	1110·1	10·11	0·111
8	1111·1000	1111·000	110·00	1·000
9	1111·1001	1111·001	110·01	1·001
10	1111·1010	1111·010	110·10	1·010
11	1111·1011	1111·011	110·11	1·011
12	1111·1100	1111·100	111·00	1·100
13	1111·1101	1111·101	111·01	1·101
14	1111·1110	1111·110	111·10	1·110
15	1111·1111	1111·111	111·11	1·111

IV. EXPERIMENTAL RESULTS AND ANALYSIS

In order to evaluate coding efficiency of the proposed method, we performed several experiments on various depth map sequences (Newspaper, Lovebird1, Undo Dancer, and GT-Fly) with YUV 4:2:0 8 bits per pixel (bpp) format. Detail encoding parameters for the reference software are shown in Table IV.

We implemented our proposed method in the HEVC test model (HM) version 4.0 [11]. Test sequences are intra only coded and CABAC is used as a entropy coder. In the experiments, we first compare the coding efficiency of our proposed method to those of other reference schemes. We compared our proposed scheme to other depth map coding methods: HEVC lossless coding and HEVC near-lossless coding. Experimental results are shown in Table IV. For the comparison, we used *Bit-rate* and $PSNR_D$ which represents the PSNR value of the decoded depth map. *Bit-rate* and $PSNR_D$ values for near-lossless coding are calculated.

TABLE IV. MAIN EXPERIMENTAL CONDITIONS

Parameter	Settings
MaxCUWidth	64
MaxCUHeight	64
IntraPeriod	1 (only intra coding)
QP	10 (near-lossless)
SymbolMode	1 (CABAC)

In Table V, Δ*Saving Bits* values are also represented. To calculate Δ*Saving Bits*, the bit-rate result of HEVC lossless coding is used as an anchor, as shown in Eq. (3).

$$\Delta Saving\ Bits(\%) = \frac{Bitrate_{Method} - Bitrate_{Anchor}}{Bitrate_{Anchor}} \times 100 \quad (3)$$

From the Δ*Saving Bits* result, we can verify that the proposed method improves the coding performance by approximately 16.59% bit saving, compared to HEVC lossless depth map coding. Moreover, the proposed method can reduce about 0.54% bit than HEVC near-lossless depth map coding.

TABLE V. THE PERFORMANCE COMPARISON

Sequence	Method	Bit-rate (kbps)	ΔSaving Bits (%)	$PSNR_D$ (dB)
Newspaper view 6, 30fps 1024×768	lossless HEVC	10067.52	-	99.99
	near-lossless HEVC	9900	-1.66	59.08
	Proposed method	9794.4	-2.71	59.11
Lovebird1 view 6, 30fps 1024×768	lossless HEVC	9599.28	-	99.99
	near-lossless HEVC	6211.2	-35.30	59.89
	Proposed method	6200.88	-35.40	59.90
Undo Dancer view 2, 25fps 1920×1088	lossless HEVC	4634.6	-	99.99
	near-lossless HEVC	2552.2	-44.93	67.36
	Proposed method	2527.8	-45.46	67.40
GT-Fly view 1, 25fps 1920×1088	lossless HEVC	9778	-	99.99
	near-lossless HEVC	5900.8	-39.65	63.76
	Proposed method	5876.8	-39.90	63.75
Average	lossless HEVC		-	99.99
	near-lossless HEVC		-16.05	62.43
	Proposed method		-16.59	62.45

(a) Original view (b) HEVC lossless coding (c) HEVC near-lossless coding (d) Proposed method

Figure 3. The synthesized view quality comparison after depth map coding (*Balloons*, view 4).

Since the depth map is 3D information to support the virtual view synthesis, its quality should be evaluated in terms of rendering quality. Using decoded depth maps, we generate the synthesized view by the view synthesis reference software (VSRS) 3.5 [12]. VSRS 3.5 is provided by Nagoya university.

In Fig. 3, the synthesized virtual views of *Balloons* using decoded depth maps of HEVC lossless coding, HEVC near-lossless coding, and the proposed method. Specifically, we encode and decode view 3 and view 5 of the *Balloons* sequence, and we synthesize the virtual view 4 using the decoded depth maps. From Fig. 3, we can confirm that the proposed method provides almost same quality of the synthesized virtual view.

For more accurate quality comparison, we used objective and subjective quality measures. For objective quality of the synthesized view, we use the PSNR value. In order to measure subjective quality, the structural similarity (SSIM) [13] metric and video quality metric (VQM) [14] are used.

Table VI shows results of some test sequences. Here, the anchor is HEVC lossless depth map coding. From the experimental results, we confirmed that the proposed near-lossless depth map coding method achieves a good gain by reducing bit-rate without the significant degradation of quality of the rendered view.

TABLE VI. SYNTHESIZED VIEW QUALITY (NEWSPAPER)

	HEVC Near-lossless Coding	Proposed Method
ΔPSNR$_D$	-0.0229	+0.0015
ΔSSIM$_S$	-0.0001	-0.0001
ΔVQM	0	0

V. CONCLUSION

In this paper, we proposed an efficient near-lossless depth map coding method in HEVC. Since HEVC is developed for lossy coding, for near-lossless coding, some modifications should be required. In order to improve the compression performance of HEVC near-lossless depth map coding, we proposed two method: large coefficients clipping and binarization using the limited codeword length GR code. Experiment results demonstrated that coding efficiency of our proposed method outperforms that of other reference schemes, including HEVC lossless and near-lossless coding methods. Moreover, we can verified that rendered virtual view quality of the proposed scheme is almost same with that of the lossless coding scheme. Thus, we expect that proposed near-lossless depth coding could replace lossless depth coding.

ACKNOWLEDGMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (No. 2011-0030822).

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