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Multi-view Rate Control based on HEVC for 3D Video Services

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Abstract

In this paper, we propose two rate control algorithms for multi-view extension of HEVC with two rate control algorithms adopted in HEVC and analyze the multi-view rate control performance. The proposed multi-view rate controls are designed on HEVC-based multi-view video coding (MV-HEVC) platform with consideration of high-level syntax, inter-view prediction, etc. not only for the base view but also for the extended views using the rate control algorithms based on URQ (Unified Rate-Quantization) and R-lambda model adopted in HEVC. The proposed multi-view rate controls also contain view-wise target bit allocation for providing the compatibility to the base view. By allocating the target bitrates for each view, the proposed multi-view rate control based on URQ model achieved about 1.83% of average bitrate accuracy and 1.73dB of average PSNR degradation. In addition, about 2.97% of average bitrate accuracy and 0.31dB of average PSNR degradation are achieved with the proposed multi-view rate control based on R-lambda model.

Keywords : HEVC, multi-view video coding, rate control, URQ model, R-lambda model

Ⅰ. Introduction

After the conventional H.264/AVC, the market demand of ultra high definition (UHD) beyond HD and Full-HD video has been increasing. Therefore, ISO/IEC MPEG (Motion Picture Experts Group) and ITU-T VCEG (Video Coding Experts Group) set up JCT-VC (Joint Collaborative Team on Video Coding) and started standardization of HEVC (High Efficiency Video Coding) for compression of upcoming UHD videos[1]. Thus, the work on multi-view extension of HEVC, MV-HEVC, also started by MPEG 3DV group. During the JCT-VC meeting, URQ and R-lambda model-based rate control algorithms for single-view video were adopted and implemented on the reference software[2~4]. However, none of the rate control algorithm has not been proposed for multi-view extension of HEVC.

The rate control is very important for practical uses of video coding standard for services on the limited channel bandwidth to prevent buffer overflow or underflow. From the multi-view coding perspectives, it leads a large amount of bits compared to the single-view video, because it has multiple extended views to provide the view-scalability. Therefore, we propose a multi-view rate control algorithms with one additional tool to assign a target bitrate for each view to retain the bitrate and compatibility of the base view.

This paper is organized as follows. In Section Ⅱ, we introduce the current rate control algorithms on HM reference software. In Section Ⅲ, we describe our proposed multi-view rate control algorithms and show the performance evaluation results and analysis

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of the proposed algorithms. Finally, in Section Ⅳ, we summarize and conclude about this paper and suggest further work items for proper multi-view rate control.

Ⅱ. The Rate Control Algorithms In HEVC

2.1. URQ MODEL-BASED RATE CONTROL

URQ model-based rate control algorithm[2] is based on the conventional RQ (Rate-Quantization) model[5] in H.264/AVC reference software. It uses the model of statistical relationship between bitrate and quantization parameter. However, HEVC, different from H.264/AVC, has quad-tree coding unit structure of CU (Coding Unit) with diverse sizes from 64×64 to 8×8. Thus, URQ model-based rate control was designed with consideration of this various size of CU[2] by normalizing the number of bits in a coding unit to the pixel-based average bits. As a result, bpp (bits per pixel) and MAD (Mean Absolute Difference) are used to measure the target bits and texture complexity, respectively. At the frame level, the Qstep (quantization step size) value is found using the URQ model as

$$\frac{T_{i(j)}}{N_{\pi xels,\, i(j)}} = \alpha \cdot \frac{MAD_{pred,\, i(j)}}{Qstep_i^2(j)} + \beta \cdot \frac{MAD_{pred,\, i(j)}}{Qstep_i^2(j)} \tag{1}$$

where $T_i(j)$ is the number of given target bits and $N_{\pi xel,i}(j)$ is the number of pixels of the jth frame in the ith GOP (Group Of Picture). Therefore, the left term of Eq.(1) means the bpp of a frame. $MAD_{pred,i}(j)$ is the predicted pixel-based MAD value from the previously coded frame. α and β are model parameters. The quantization step size, $Qstep_i(j)$, can be derived for the current frame. At CTU(CodingTreeUnit) level, similar to the frame level rate control, the Qstep is derived as Eq.(1) using the target bits based on the remaining bits for the current frame and predicted MAD from the collocated CTU in the previous frame.

2.2. R-lambda Model-Based Rate Control

R-lambda model-based rate control algorithm is designed based on the assumption that the relationship between bitrate and distortion can be modeled using hyperbolic function as

$$D(\mathrm{R}) = CR^{-K} \tag{2}$$

where D is the distortion measured using MSE (MeanSquaredError), R is the pixel-based bitrate and C and K are model parameters. Based on the model in Eq.(2), the slope of R-D curve, lambda, can be expressed as

$$\lambda = -\frac{\partial D}{\partial R} = CK \cdot R^{-K-1} = \alpha \cdot R^{\beta} 1 \tag{3}$$

where α and βare parameters related to input videos. To calculate the target bits for apicture, target bits of the current GOP and coded bits for previously encoded pictures in the current GOP are considered as

$$T_{CurrPic} = \frac{T_{GOP} - Coded_{GOP}}{\sum_{NotCodedPic} \omega_i} \cdot \omega_{CurrPic} \tag{4}$$

where T_{GOP} and $T_{CurrPic}$ are the target bits of the current GOP and the current picture, respectively. $Coded_{GOP}$ is the amount of bits generated in previously encoded pictures in the current GOP. ω is the pre-defined weighting factor for allocation of bits for a picture based on a hierarchical coding structure. After allocation of bits for apicture, CTU level bit allocation is conducted, similar to picture level bit allocation.

Ⅲ. The Proposed Rate Control Algorithms for Multi-View Video Coding

As described in Section Ⅱ, there are two single-view rate control algorithms adopted in HEVC. MV-HEVC is designed based on HEVC and only the base view is compatible to HEVC. In contrast with the base view, the extended views in MV-HEVC contains additional bits for high-level syntax (HLS) and inter-view prediction by referencing the reconstructed neighboring views, compared to the base view. Because the conventional rate control algorithms mainly concerns the generated bits from the coding loop and texture complexity of a unit, the bits for HLS and the number of reference picture should be considered for rate control of the extended views. Therefore, in case of the proposed HMVRC (HEVC-based Multi-View Rate Control) based on R-lambda model, the target bits for a CTU can be derived as Eq. (5) and Eq. (6)

$$T_{CurCTU} = \frac{T_{CurrPic} - Bit_{header} - Coded_{Pic}}{\sum_{CodedCTUs} \omega_i} \cdot \ \omega_{CurrCTU} \quad (5)$$

$$Bit_{header} = Bit_{header,\,slice} + Bit_{header,\,extension} \quad (6)$$

where $T_{CurrCTU}$ and $Coded_{Pic}$CodedPic are the target bits of the current CTU and generated in previously encoded CTUs in the current picture. Bit_{header} Bitsheader is the amount of bits for HLS. Figure. 1 shows a block diagram of HMVRCs which is rate control-selectable algorithm based on URQ or R-lambda model.

The proposed HMVRCs are also designed to provide an additional functionality which is for the compatibility of the base view to HEVC using view-wise bitrate allocation. It is under consideration of view scalability in single-view applications which enable to access only the base view at the same bitrate. This view-wise target bitrate assignment also make the view-wise evaluation and comparison comfortable between URQ and R-lambda model-based rate control algorithms.

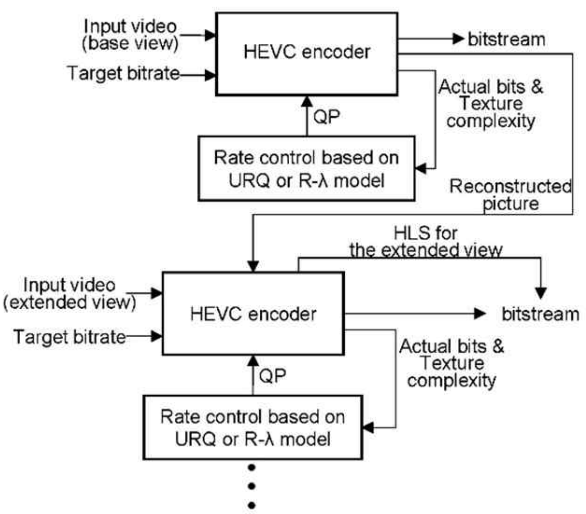


Fig. 1. A block diagram of the proposed HMVRCs.

Ⅳ. Performance Analysis of Rate Control for Multi-View Video Coding

Using the proposed HMVRCs described in Section Ⅲ, we evaluated the rate control performance under CTC (Common Test Condition) for CBR (Constant Bit Rate) case using JCT-3V sequences. To assign the target bitrate for each sequence and each view, we encoded all the sequences with constant QPs for 4 rate points according to CTC[7]. Then, we set those generated bitrates as target bitrates to compare the bitrate accuracy and PSNR degradation.

Table 1 and 2 show the bitrate accuracy of

Table 1. Bitrate accuracy of HMVRC based on URQ model.

Sequences	Δ kbps accuracy for each view (%)			Average of total Δ kbps accuracy (%)
	view0	view1	view2	
Balloons	1.55	1.86	1.80	1.66
Kendo	1.70	1.81	1.89	1.76
Newspaper	1.10	0.73	0.75	0.82
Gtfly	1.93	3.43	1.69	2.07
PoznanHall2	1.77	2.47	2.68	2.02
PoznanStreet	2.14	3.92	2.14	2.39
Dancer	1.98	2.83	2.05	2.10
Average	1.74	2.44	1.85	1.83

Table 2. Bitrate accuracy of HMVRC based on R-lambda model.

Sequences	Δ kbps accuracy for each view (%)			Average of total Δ kbps accuracy (%)
	view0	view1	view2	
Balloons	2.04	3.90	3.78	2.74
Kendo	1.23	3.19	2.81	1.91
Newspaper	2.03	3.70	3.27	2.59
Gtfly	2.70	4.74	5.12	3.20
PoznanHall2	3.16	2.54	2.86	2.94
PoznanStreet	4.99	5.90	6.29	5.30
Dancer	2.02	2.37	2.66	2.16
Average	2.59	3.76	3.83	2.97

Table 3. PSNR degradation of HMVRC based on URQ model.

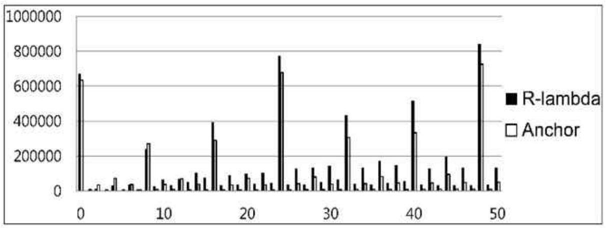
Sequences	PSNR degradation for each view (dB)			Average of total PSNR degradation (dB)
	view0	view1	view2	
Balloons	-1.89	-1.82	-1.78	-1.83
Kendo	-2.74	-2.70	-2.33	-2.58
Newspaper	-2.39	-2.35	-2.40	-2.38
Gtfly	-1.05	-1.06	-1.07	-1.06
PoznanHall2	-0.53	-0.42	-0.51	-0.49
PoznanStreet	-2.41	-2.06	-2.20	-2.22
Dancer	-1.53	-1.54	-1.56	-1.55
Average	-1.79	-1.70	-1.69	-1.73

Table 4. PSNR degradation of HMVRC based on R-lambda model.

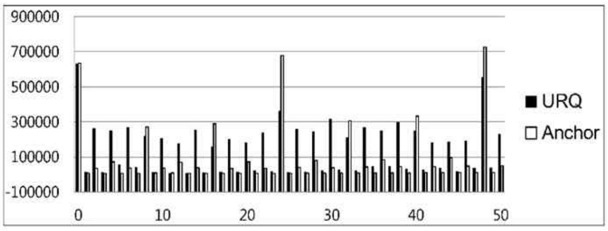
Sequences	PSNR degradation for each view (dB)			Average of total PSNR degradation (dB)
	view0	view1	view2	
Balloons	-0.11	-0.40	-0.37	-0.29
Kendo	-0.21	-0.26	-0.26	-0.24
Newspaper	-0.16	-0.51	-0.57	-0.42
Gtfly	-0.09	-0.24	-0.24	-0.19
PoznanHall2	-0.53	-0.78	-0.74	-0.68
PoznanStreet	-0.13	-0.28	-0.29	-0.23
Dancer	-0.09	-0.11	-0.11	-0.10
Average	-0.19	-0.37	-0.37	-0.31

HMVRCs based on URQ and R-lambda models for all views, respectively. As seen in Table 1 and 2, HMVRCs based on URQ model achieves about 1% higher bitrate accuracy than HMVRC based on R-lambda model.

Table 3 and 4 show the view-wise PSNR degradation using the propose HMVRCs. Rate control often degrades PSNR that is why it derives the QP for each unit based on the instantaneous bitrate and buffer occupancy during encoding. As shown in Table 3 and 4, the average amount of PSNR degradation of HMVRC based on R-lambda model is less about 1.4dB. However, the difference of PSNR degradation between two algorithms is caused by R-lambda model-based rate control which considers hierarchical coding structure and allocates the target bits according to the picture-level coding depth. In contrast, URQ model-based rate control evenly allocates the target bit for each picture regardless of hierarchical coding structure. According to this target bit allocation of each mode, Fig. 1 shows the



(a) HMVRC based on R-lambda model



(b) HMVRC based on URQ model

Fig. 2. Frame-wise generated bits for each HMVRC rate control algorithm.

frame-wise actual generated bits (y-axis) of the base view of 'GTFly' sequence at rate 1 (the highest bitrate case) plotted from frame 0 to 50 (x-axis) using HMVRCs with each rate control mode, respectively. As shown in Fig.1, HMVRC based on URQ model generates bits for each frame more steadily than HMVRC based on R-lambda model.

V. CONCLUSION

In this paper, we summarized the two rate control algorithms adopted on HM reference software and embedded two rate control algorithms appropriately for multi-view coding with view-wise target bitrate allocation. From performance evaluation, the proposed HMVRC based on URQ model showed better bitrate accuracy than that based on R-lambda model. For objective quality, the HMVRC based on R-lambda model yields higher PSNR than that based on URQ model. Those two rate control algorithms need to be improved for bitrate accuracy in the extended views as they showed less accurate than that in the base view. To alleviate this problem, we may need to precisely predict texture complexity using correlation between the base and extended views.

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