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| *Title:* | **Adaptive rate control for HEVC** | | |
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# Abstract

This contribution provides improvements of the rate control scheme proposed in JCTVC-I0433. The proposed rate control scheme implemented on HM7.0 is modified mainly in two aspects. One is that hypothetical reference decoder (HRD) is used to adjust bit allocation. The other is that the quantization scale is used in the R-Q model instead of using QP directly. Compared with the original rate control scheme in HM7.0, the average BD-RATE computed using piece-wise cubic interpolation can be up to -28.5% for RA-main (for LP-main: -21.1%; LB-main: -20.7%).

# Introduction

A rate control algorithm has been proposed by JCTVC-H0213 and adopted at the San Jose meeting. However, the performance of the rate control scheme is not so good. The average BD-RATE loss of H0213 is up to 45.4% for RA-main (LB-main: 29.5%, LP-main: 28.2%) on HM7.0. For the worst case, the loss is more than 70%, which is unacceptable. Based on the ABR (Adaptive Bit Rate) rate control scheme used in the popular x264 codec, a new adaptive rate control scheme is proposed for HEVC in JCTVC-I0433. Its performance is better than H0213 and comparable with the anchor. In this proposal, the rate control scheme is further improved to reduce the PSNR fluctuation. And SSIM value is calculated as an additional measure of performance.

# Proposed rate control algorithm

**2.1 Rate modeling**

Based on the rate distortion modeling study of the rate control algorithm in x264, a linear R-D model is proposed for HEVC, as shown in Equation (1). In the proposed model, SATD (Sum of Absolute Transformed Difference) is used as complexity estimation. Besides, the complexities of previously encoded frames are taken into account in the proposed rate model, providing efficient information to smooth the coding performance. The proposed rate model is shown as,

 (1)

where *α* is the model parameter. *R* is the coding rate. *X* is the complexity estimation for the current picture. *qscale* is the quantization scale. *X* is computed as:

 (2)

*n* is the current frame number. *QPn*-1 is the quantization parameter of the (*n*-1)th frame. *Rn*-1 is the actual bits of the (*n*-1)th frame. *λ* is a constant, the recommended value is 0.6. *wi*is the weight of *SATD* values of previously encoded frames. *wi*is defined as:

 (3)

The relationship between quantization scale *qscale* and quantization parameter *QP* is shown as follows:

 (4)



**Figure. 1: The relationship between the generated bits and the estimated bits. QP is set to 32.**

Figure.1 shows the performance of the proposed rate model. The test sequence is encoded with a fixed quantization parameter. Obviously, the mismatch of generated bits and estimated bits per frame is relatively small.

**2.2 Rate control scheme**

Considering the difference between LD and RA settings, the proposed rate control algorithm is designed discriminatingly. A GOP level QP adjustment strategy is designed for the RA setting to maintain the generated bitrate with the target. Frame level adaptive QP adjustment schemes are designed for both LD and RA settings to make the bitrate match the target requirement as soon as possible.

The proposed rate control algorithm is detailed as follows:

**2.2.1 Rate control algorithm for LD setting**

**Step 1:** An initial quantization scale is setfor each frame type as a clip boundary.

 (5)

where *qscale0* is the initial quantization scale.

**Step 2:** Average bit allocation for the current frame is applied:

 (6)

where *BR* is the target bitrate, *Fr* is the frame rate.

**Step 3:** The target bit *T* is clipped to meet the requirement of HRD boundaries, shown as:

 (7)

 (8)

 (9)

where *type* is the picture type of the current frame, *N* is the number of frames been encoded, *G* is the generated bits by all encoded frames. *BufferSize* is the Size of virtual buffer.

**Step 4:** Estimate the frame complexity SATD by doing rough motion estimationover LCUs, which can be merged with motion estimation of CUs in the future without increasing complexity. And Experimental results show that this pre-analysis hardly effects the overall encoding time.

**Step 5:** Calculate the quantization scale using the rate model proposed in section 2.1. As for the first frame of the sequence, a constant valueis used to substitute , defined as:

 (10)

where *SATD0* is the SATD value of the first frame, is a constants set to 4 in the experiments.  is the same as that in the rate model.

**Step 6:** Clip the calculated quantization scale into a small range of the quantization scale of the nearest frame of the same type.

 (11)

As for frames of depth 0, its quantization scale is no less than frames of other depth.

 (12)

**Step 7:** Mapping the quantization scale *qscale’* to quantization parameter *QP* using equation (4).

**Step 8:** Implement adaptive frame level QP adjustment: regulate the quantization parameter for the current frame based on the difference between the generated bits and the target bits so far.

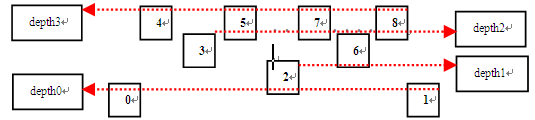
 (13)

whereare constants, andis between 0~1. is bigger than 1. is the difference between the target bits and the generated bits of the encoded frames.

**Step 9:** The *QP* value is further clipped between the minimum and maximum QP value allowed. The range is set to (10, 46) in experiments.

**Step 10**: Go to Step 2 to continue coding the next frame until the sequence is finished.

**2.2.2 Rate control algorithm for RA setting**



**Figure. 2: The hierarchical B structure in RA setting.**

**Step 1:** An initial quantization scale is setfor each depth as a clip boundary.

 (11)

where *qscale0* is the initial quantization scale.

**Step 2-5:** Same as that of the LD setting.

**Step 6:** As shown in Figure 2, the quantization scale of the lower depth should be no bigger that of the upper depth.

 (12)

Clip the calculated quantization scale into a small range of the quantization scale of the nearest frame of the upper depth.

 (13)

As for frames of depth 0, its quantization scale is clipped using the quantization scale of the nearest frame of the same depth.

 (14)

**Step 7:** Mapping the quantization scale *qscale’* to quantization parameter *QP* using equation (4). As for unreferenced frames, QP determination is shown as:

 (15)

where *QP1* and *QP2* are the quantization parameters of two nearest reference frames respectively. *offset* is a constant set to 1. And , , where POC is the picture order count for display order. And the resulted *QP* should be no less that *temporal[depth-1]+1*.

**Step 8:** Perform GOP level adaptive QP adjustment for I frames according to the coding status of the previous GOP.

 (16)

where *Rprev, Tprev* are the generated and target bits of the previous GOP respectively. *QPave\_prev* is the average QP of the previously encoded GOP. For the first GOP this step is skipped.

**Step 8:** Implement adaptive frame level QP adjustment: regulate the quantization parameter for the current frame based on the difference between the generated bits and the target bits so far.

 (17)

whereare constants, andis between 0~1, is bigger than 1. is the difference between target bits and generated bits of encoded frames. *depth\_i* is the depth of the current picture.

**Step 10:** Same as Step 9 of the LD setting. The *QP* value is further clipped between the minimum and maximum QP value allowed. The range is set to (10, 46) in experiments.

**Step 11:** Go to Step 2 to continue coding the next frame, until the sequence is finished.

# Experimental results

The proposed rate control scheme is implemented on HM7.0 reference software. The control accuracy and R-D performance are compared with that of the init rate control scheme and HM7.0, respectively. PSNR curves for typical test sequences are also provided.

**Table 1. Rate control performance with RA main compared with HM7.0 init RC**



**Table 2. Rate control performance with LB main compared with HM7.0 init RC**



**Table 3. Rate control performance with LP main compared with HM7.0 init RC** 

**Table 4. Δkbps and ΔPSNR of HM7.0 init RC and the proposed RC compared with HM7.0 for RA, LB, and LP cases**



Table 1-3 show the BD-RATE gain of the proposed method compared with the init rate control scheme of HM7.0. Obviously the proposed method outperforms the original one in terms of BD-RATE. Table 4 shows the performance in terms of Δkbps and ΔPSNR of original and the proposed rate control scheme compared with HM7.0 respectively.

**Table 5. Rate control accuracy and performance with RA main compared with HM7.0**



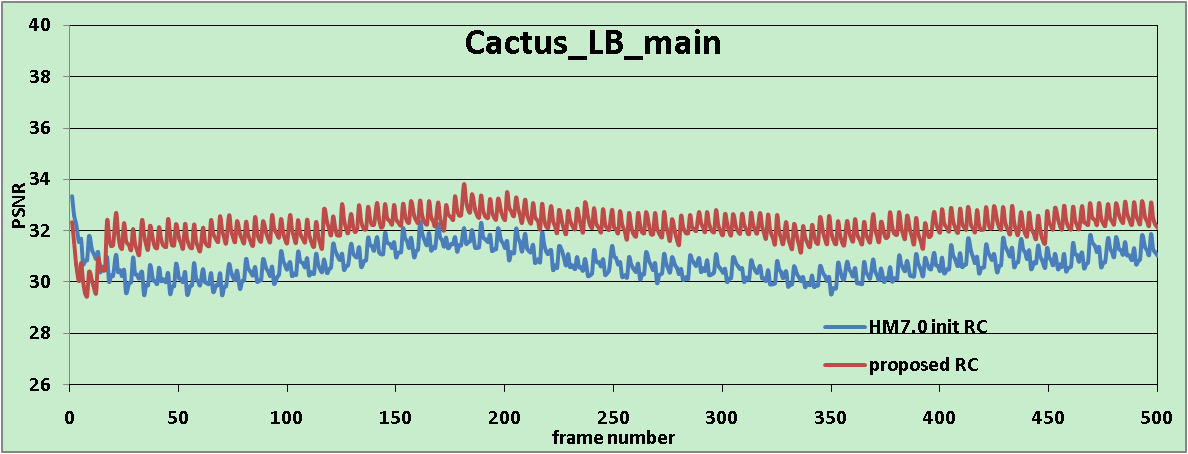
**Table 6. Rate control accuracy and performance with LB main compared with HM7.0**



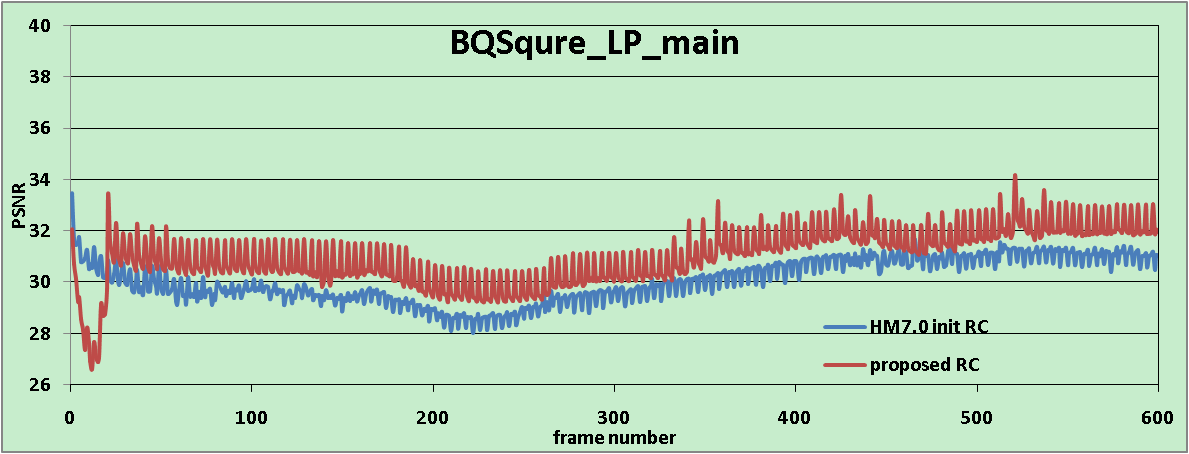
**Table 7. Rate control accuracy and performance with LP main compared with HM7.0**



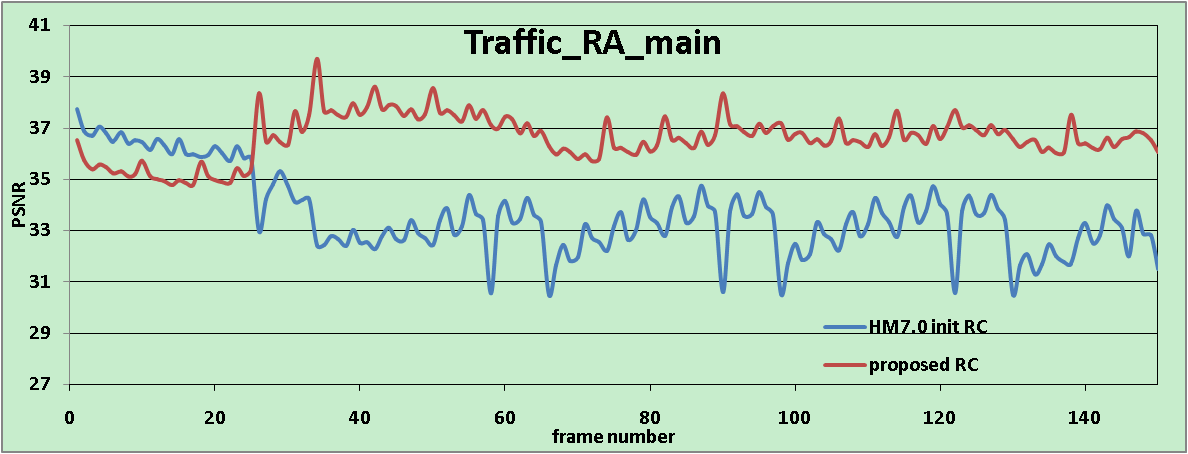
Table 5-7 show the control accuracy and R-D performance of the proposed method compared with HM7.0. The proposed method show comparable R-D performance and the control accuracy is mostly within 1%.



**Figure.3, PSNR curve of “Cactus” with LB main**



**Figure.4 PSNR curve of “BQSqure” with LP main**



**Figure.5, PSNR curve of “Traffic” with RA main**

Figure 3-5 show the PRNR curves of typical test sequences, obviously, the proposed rate control scheme results in smoothness of quality.

**Table 8. SSIM value of** **HM7.0 anchor, init rate control and proposed rate control scheme**



Table 8 shows the SSIM value HM7.0 anchor, init rate control and proposed rate control scheme. It can be seen that the SSIM values under three conditions are almost the same, while the proposed rate control scheme beats the init rate control algorithm of HM7.0.

# Reference

1. H. Choi, J. Nam, J. Yoo, D. Sim, and I. V. Bajić, “Rate control based on unified RQ model for HEVC,” JCT-VC of ITU-T SG16 WP3 and ISO/IEC JTC1/SC29/WG11, JCT-VC H0213 (m23088), San José, CA, USA, Feb. 2012
2. Frank Bossen, “Common test conditions and software reference configurations” , JCTVC-H1100, 8th JCT-VC Meeting, San Jose, CA, USA, 1-10 February, 2012.

# Patent rights declaration(s)

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