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

This contribution provides a frame level rate control scheme for HEVC, which originates from ABR (Adaptive Bitrate) used in the popular x264 codec with fine tuning for HEVC. The proposed rate control scheme is designed deliberately for Low delay and Random Access coding respectively and implemented into HM6.1. Compared with the original rate control scheme proposed by JCTVC-H0213, the average BD-RATE computed using piece-wise cubic interpolation can be up to -23.7% for RA-main (for LP-main: -18.3%; LB-main: -19.1%).

# Introduction

Rate control is indispensable for the real application of video coding standards. A rate control algorithm has been proposed by JCTVC-H0213 and adopted at the last San Jose meeting. However, the performance of H0213 is not so good or even worse than the HM6.1 anchor. The average BD-RATE loss of H0213 may be up to 49.5% for RA-main (LB-main: 27.3%, LP-main: 25.1%). For the worst case, the loss is more than 3dB, 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 this proposal. The rate control algorithm is designed carefully for LD and RA setting respectively.

As ABR for x264, the complexity of previously encoded frames is used for experimental rate model modeling, and the experimental results show that the rate modeling can achieve accurate rate estimation for HEVC. The video buffer verifier (VBV) operation model used in x264 is established to avoid overflow and underflow of client buffer. Moreover, adaptive QP adjusting strategies are set up to ensure the generated bitrate meets the target requirement with comparable quality as HM6.1.

# 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. *QP* is the quantization parameter. *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)



**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. Finally, the quantization parameter is adjusted to make sure no buffer overflow or underflow.

The proposed rate control algorithm is detailed as follows:

**2.2.1 Rate control algorithm for LD setting**

**Step 1:** Initialize the VBV buffer. Set the initial buffer fullness, where is the buffer size. Letdenote the current buffer fullness and set;

**Step 2:** Bit allocation for the current frame, shown as,

 (3)

where *T* is the target bits, *BR* is the target bitrate and *Fr* is the frame rate.is defined as follows:

 (4)

where is the difference between the current and the initial VBV buffer fullness, andis set to 0.1 by default.

**Step 3:** 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 4:** Calculate the quantization parameter 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:

 (5)

**Step 5:** Check whether the calculated *QP* in step3 complies with the VBV buffer constraints. If not, clip *QP* to avoid buffer overflow or underflow. The detail steps are shown as:

1. If the current buffer fullnessis less than the half of the buffer size, it means the former encoded frame has consumed too much bits, so the *QP* value of current frame is increased as the following equation:

 (6)

whereis clipped between 0.5 and 1.

1. Predict the bits to be consumed by the current frame withand the SATD value of the frame, defined as:

 (7)

whereis the predicted bits count. are constants, which are updated with the final *QP* value and bits consumed after one frame is encoded.

1. If  is bigger than, then the *QP* value should be increased as following:

 (8)

1. If  is smaller than, then the *QP* value should be decreased as following:

 (9)

**Step 6:** 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.

 (10)

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 7:** For quality smoothness, *QP* derived from step6 is clipped into a small range of the *QP* value of the closest frame of the same type.

 (11)

 is 2 or 4 used in the experiments according to the bit rate fluctuation .

**Step 8:** The *QP* value is further clipped between the minimum and maximum QP value allowed. The range is set to (0, 51) in experiments.

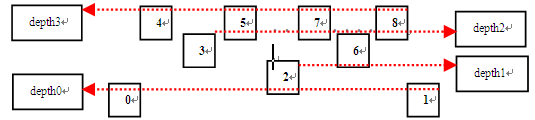
**Step 9:** Update the VBV buffer fullness after the frame is encoded using the following equation:

 (12)

wheredenotes the current buffer fullness.

**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:** For the first frame of the sequence, it is coded with an initial QP. For the other frame, average bit allocation for the current frame is applied:

 (14)

**Step 2:** Same as step3 of LD setting. 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.

**Step3:** As shown in Figure 2, for the referenced frames (frames in depth 0/1/2), QP determination is the same as step4 of LD setting. And *QP* of the unreferenced B frames (frames in depth 3) is derived from a linear interpolation method as follows:

 (15)

where  and  are the quantization parameters of two nearest reference frames respectively.  is a constant set to 1.4. And , , where POC is the picture order count for display order.

**Step4:** Perform GOP level adaptive QP adjustment for I frames according to the coding status of the previous GOP.

 (16)

where  are the generated and target bits of the previous GOP respectively.  is the average QP of the previously encoded GOP. For the first GOP this step is skipped.

**Step5:** 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. And quantization parameter of B-frames should not be less than its reference frames.

 (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.

**Step6:** For quality smoothness, *QP* derived from step5 is clipped with the *QP* value of the closest frame in the lower depth. As for frames in depth 0, the previously encoded frame in the same depth is used as an alternative.

 (18)

 is 1 or 2 used in the experiments according to the bit rate fluctuation .

**Step7:** Same as step8 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.

**Step8:** Go to Step 1 to continue coding the next frame, until the sequence is finished.

# Experimental results

The proposed rate control scheme is implemented on HM6.1 reference software. The control accuracy and R-D performance are compared with that of H0213 and HM6.1, respectively. R-D curves and PSNR curves for typical test sequences are also provided.

**Table 1. Rate control performance with RA main compared with JCTVC-H0213**



**Table 2. Rate control performance with LB main compared with JCTVC-H0213**

**Table 3. Rate control performance with LP main compared with JCTVC-H0213**



**Table 4. Δkbps and ΔPSNR of H0213 and the proposed RC compared with HM6.1 for RA, LB, and LP cases** 

Table 1-3 show the BD-RATE gain of the proposed method compared with H0213. Obviously the proposed method outperforms H0213 in terms of BD-RATE. Table 4 shows the performance in terms of Δkbps and ΔPSNR of H0213 and the proposed rate control scheme compared with HM6.1 respectively.

**Table 5. Rate control accuracy and performance with RA main compared with HM6.1**



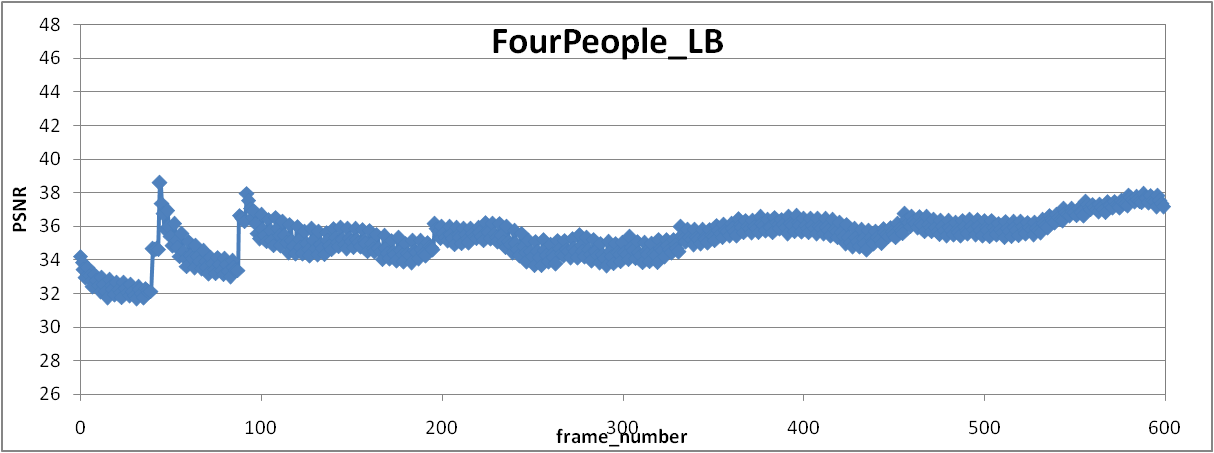
**Table 6. Rate control accuracy and performance with LB main compared with HM6.1**



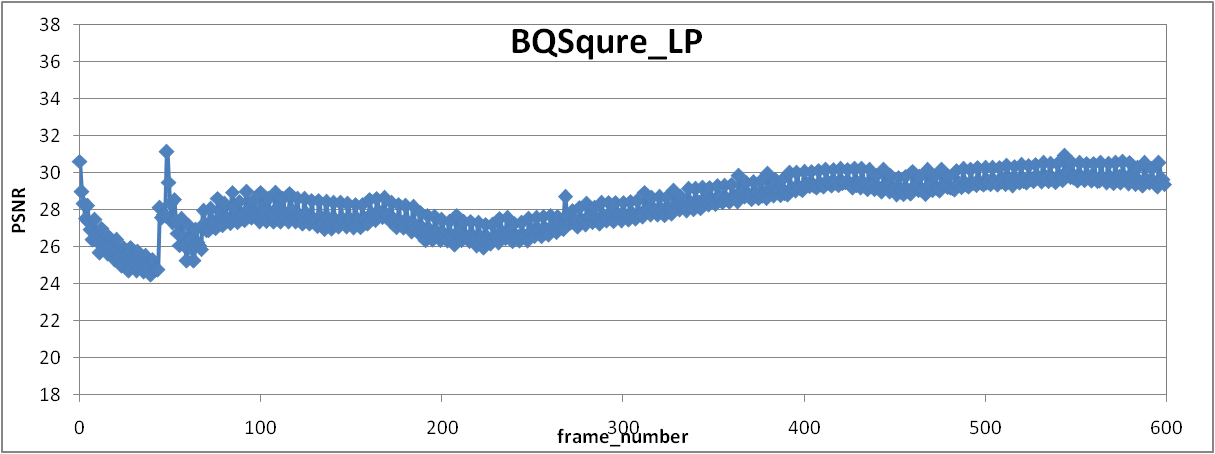
**Table 7. Rate control accuracy and performance with LP main compared with HM6.1**



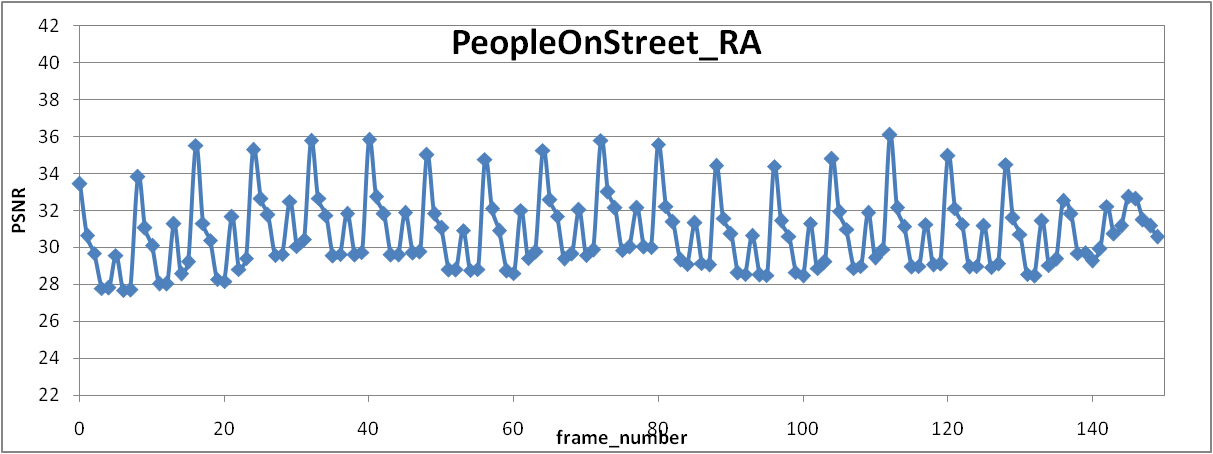
Table 5-7 show the control accuracy and R-D performance of the proposed method compared with HM5.0. The proposed method show comparable R-D performance and the control accuracy is within 2%.



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



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



**Figure.5, PSNR curve of “PeopleOnStreet” 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.

# 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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