A Rate Control Algorithm Based on Psnr-Hvs For Hevc

Yunfei Du*
School of Microelectronics, Shanghai Jiao Tong University, Shanghai, China

*Corresponding author: prometheusu@sjtu.edu.cn

Abstract. HEVC/H.265 is the latest video coding standard. It has a higher compression rate under the requirement of ensuring video image quality. However, the currently used video image quality evaluation indicators cannot better fit the subjective perception of the human visual system and cannot effectively allocate target bits and update parameters so that results in reduced video image coding quality. This paper proposes a CTU-level rate control algorithm based on the image quality evaluation factor PSNR-HVS which is more in line with the perception of the human visual system. According to the PSNR-HVS of the CTU as the weight, the target bit is assigned to the current frame to be encoded. Then calculate the actual bits and PSNR-HVS after encoding the current CTU to update the parameters of the CTU at the same position in the next frame. The experimental results show that compared with HM16.20, the subjective performance of the video after encoding is improved, and the image details are more delicate, BD-Rate = -4.6, BD-PSNR-HVS = 0.17, ΔT = 4.6%.

Keywords: HEVC, PSNR-HVS, CTU-Level, Rate Control, Human Visual System.

1. Introduction
In the current existing rate control algorithms, the new coding features introduced by HEVC are not reasonably used, and the accuracy of bit allocation and rate control cannot be achieved. For CTU-level rate control, W. Gao et al. [1] proposed a global optimization CTU-level rate control based on SSIM. They proposed a coding tree unit (CTU)-level rate control from the perspective of SSIM-based rate distortion optimization. Program to improve coding efficiency. However, compared with CTU-level RC, the above-mentioned algorithm pays more attention to frame-level RC. Although some CTU-level RC algorithms have been proposed recently [2,3,4,5,6,7], they still have many problems.

This paper proposes a PSNR-HVS-based CTU-level bit allocation algorithm and provides a parameter update algorithm.

2. Rate Control Algorithm In HEVC

2.1. Rate Control
The main work of rate control is to realize the bit allocation of the coding unit, establish the relationship model between the rate bitrate and the quantization parameter QP, and determine the model parameters at the same time. The commonly used R-Q models are: linear model, quadratic model, logarithmic model, exponential model, \(\rho\) domain model, \(\lambda\) domain model [8].
2.2. Rate Control in HEVC

The rate control in HEVC adopts a layered rate control strategy. The work mainly includes the construction of R-D model relationship (λ domain model), bit allocation, λ calculation, QP calculation, parameter update. Bit allocation adopts a layered strategy: GOP level, frame level, and CTU level respectively.

2.2.1. λ domain model

\[ \lambda = \alpha \cdot R^\beta \]  

(1)

\[ QP = 4.2005 \cdot \ln \lambda + 13.7122 \]  

(2)

Where \( \alpha \) and \( \beta \) are model parameters.

2.2.2. Bit Allocation

Average target bits of each frame of image:

\[ R_{PicAvg} = \frac{R_{target}}{f} \]  

(3)

Where \( R_{target} \) is the target bit rate and \( f \) are the frame rate.

\[ T_{GOP} = \frac{T_{PicAvg} \times (N_{coded} + SW) - R_{coded}}{SW} \times N_{GOP} \]  

(4)

\[ T_{CurrentPic} = \frac{T_{GOP} - CodedGAP}{\sum NotCodedPic \omega_i} \times \omega_{CurrentPic} \]  

(5)

\[ T_{CurrentLCU} = \frac{T_{CurrentPic} - CodedPic - Bitheader}{\sum NotCodedLCU \omega_i} \times \omega_{CurrentLCU} \]  

(6)

2.2.3. Calculate λ

\[ \lambda = \alpha \cdot R^\beta \]  

Where \( \alpha \) and \( \beta \) are model parameters, the initial values are 3.2003 and -1.367, respectively, they are empirical parameters, obtained through a large number of experiments and observations.

2.2.4. Calculate QP

\[ QP = 4.2005 \cdot \ln \lambda + 13.7122 \]  

In order to ensure smooth and continuous image quality, a clip is usually made to the QP value.

2.2.5. Update Parameters \[9\]

\[ \lambda_{comp} = \alpha_{old} \cdot bpp_{real}^{\beta_{old}} \]  

(7)

\[ \alpha_{new} = \alpha_{old} + \delta_\alpha \cdot (\ln \lambda_{real} - \ln \lambda_{comp}) \cdot \alpha_{old} \]  

(8)

\[ \beta_{new} = \beta_{old} + \delta_\beta \cdot (\ln \lambda_{real} - \ln \lambda_{comp}) \cdot \ln bpp_{real} \]  

(9)

Where \( \alpha \) is between [0.05,20] and \( \beta \) is between [-3.0, -0.1].
3. CTU-Level Rate Control Algorithm Based On PSNR-HVS

3.1. Innovation
Use PSNR-HVS to build Rate-Distortion Model; build a new RDO model for CTU-level rate control, in the process of rate-distortion optimization in CTU inter-frame mode, Replace the distortion item in the RD Cost calculation with PSNR-HVS; construct a new CTU bit allocation scheme and weight update scheme.

3.2. PSNR-HVS
The PSNR-HVS indicator processes three aspects of the image: error sensitivity, structural distortion, and edge distortion.

3.2.1. Error Sensitivity
\[ E_r = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} [(x(i,j) - y(i,j))^2] \]
\[ PSNR_E = 10 \log_{10} \frac{3}{E_r + E_g + E_b} \]

Where \( x(i,j) \) represents the reference image, and \( y(i,j) \) represents the distorted image. \( E_r \) and \( E_g \) and \( E_b \) respectively represent the error calculated under the R/G/B component.

3.2.2. Structural Distortion
\[ S_e = \frac{1}{N} \sum_{i=1}^{N} \left( 0.5 \times [Xa_i - Ya_i]^2 + 0.25 \times [Xp_i - Yp_i]^2 + 0.25 \times [Xb_i - Yb_i]^2 \right) \]
\[ PSNR_S = 10 \log_{10} \left[ \frac{3}{S_r + S_g + S_b} \right] \]

3.2.3. Edge Distortion
\[ ED_e = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} [(x_e(i,j) - y_e(i,j))^2] \]
\[ PSNR_{ED} = 10 \log_{10} \left[ \frac{3}{ED_r + ED_g + ED_b} \right] \]

Where \( x_e(i,j) \) represents the edge maps of the original image; \( y_e(i,j) \) represents the edge maps of the distorted image. The Canny edge detection algorithm is used to calculate the edge distortion.

3.2.4. Algorithm Implementation Details
(1) Target Bits Allocation
\[ R_j = \frac{k_j}{\sum_{i=1}^{N} k_i} \times R_{Pic} \]

CTU code rate information is counted, and the number of remaining uncoded CTU bits available is adjusted according to the budget and the actual number of bits generated. The adjustment factor is:
\[ \omega_a = 1 - \frac{\sum_{j=1}^{N} (R_{actual,\text{pic}} - R_p)}{R_{Pic}} \]
Where $R_{\text{actual, pic}}$ is the actual number of bits generated, and $R_p$ is the target number of bits. The adjusted bit allocation formula is:

$$R_j = R_j \times \omega_a$$  \hspace{1cm} (18)

(2) Model Parameters Update

$$k_{\text{new}} = k_{\text{old}} - \delta_k \left( D_{\text{real}} - D_{\text{comp}} \right) \ln R_{\text{real}}$$  \hspace{1cm} (19)

Where $k_{\text{old}}$ is the model parameter of the CTU at the same position in the previous frame, with an initial value of 2.3; $D_{\text{real}}$ is the actual distortion of the current CTU after encoding; $D_{\text{comp}}$ is the actual distortion of the CTU at the same position in the previous frame; $R_{\text{real}}$ is the actual bit after encoding the current CTU number.

4. Experimental Results and Analysis

4.1. Test Environment Configuration

| Parameters                  | Contents                      |
|-----------------------------|-------------------------------|
| Platform                    | HM16.20                       |
| GOP Structure               | LP-main (IPPP)                |
| GOP SIZE                    | 4                             |
| CTU SIZE                    | 64 * 64                       |
| Number of Frames            | 300                           |
| Hierarchical Bits Allocation| 0                             |
| YUV Format                  | 4:2:0                         |
| Frame Rate                  | 30fps                         |
| Configuration profile       | encoder_lowdelay_P_main.cfg   |
| else                        | HM default                    |

4.2. Test Results and Analysis

4.2.1. R-D performance analysis

| Sequence | BD-Rate(%) | BD-PSNR-HVS |
|----------|------------|-------------|
| Class B  | -4.1       | 0.11        |
| Class C  | -3.7       | 0.17        |
| Class D  | -6.3       | 0.24        |
| Class E  | -4.2       | 0.13        |
| Average  | -4.6       | 0.17        |

Compared with HM16.20, the algorithm in this paper has BD-Rate = -4.6 and BD-PSNR-HVS = 0.17. Therefore, the overall performance is improved to achieve the goal of more effectively and accurately allocating code rate resources to CTUs and improving the subjective quality of images.
4.2.2. Complexity Analysis

Table 3 Encoding Time Overhead

| Sequence | ΔT(%) |
|----------|-------|
| Class B  | 4.1   |
| Class C  | 4.0   |
| Class D  | 6.3   |
| Class E  | 3.8   |
| Average  | 4.6   |

\[ \Delta T = \frac{T_{\text{proposed}} - T_{\text{original}}}{T_{\text{original}}} \times 100\% \]  \hspace{1cm} (20)

Compared with HM16.20, the coding time of the algorithm in this paper increases by 4.6% on average, indicating that the complexity of the algorithm increases and the coding time overhead increases. The increased time mainly occurs in the calculation of edge distortion and structural distortion, so for better performance, sacrificing part of the time overhead is acceptable overall.

5. Conclusions

This article uses the distortion index PSNR-HVS to build a new RDO model to be used for CTU-level rate control. After the CTU is encoded, the weight of the CTU at the same position in the next frame is updated based on the actual distortion of the current CTU and the actual distortion of the CTU at the same position in the previous frame. This paper achieves better coding performance improvements.

References

[1] W. Gao, S. Kwong, Y. Zhou and H. Yuan, "SSIM-Based Game Theory Approach for Rate-Distortion Optimized Intra Frame CTU-Level Bit Allocation," in IEEE Transactions on Multimedia, vol. 18, no. 6, pp. 988-999, June 2016.

[2] T. Wiegand, G. J. Sullivan, G. Bjontegaard and A. Luthra, "Overview of the H.264/AVC video coding standard," in IEEE Transactions on Circuits and Systems for Video Technology, vol. 13, no. 7, pp. 560-576, July 2003.

[3] S. Li, M. Xu, Z. Wang and X. Sun, "Optimal Bit Allocation for CTU Level Rate Control in HEVC," in IEEE Transactions on Circuits and Systems for Video Technology, vol. 27, no. 11, pp. 2409-2424, Nov. 2017.

[4] M. Wang, K. N. Ngan and H. Li, "Low-Delay Rate Control for Consistent Quality Using Distortion-Based Lagrange Multiplier," in IEEE Transactions on Image Processing, vol. 25, no. 7, pp. 2943-2955, July 2016.

[5] W. Gao, S. Kwong and Y. Jia, "Joint Machine Learning and Game Theory for Rate Control in High Efficiency Video Coding," in IEEE Transactions on Image Processing, vol. 26, no. 12, pp. 6074-6089, Dec. 2017.

[6] Zhao D, Zhou Y, Wang D, et al. Effective macroblock layer rate control algorithm for H.264/AVC [J]. Computers & Electrical Engineering, 2011, 37(4):550-558.

[7] Zhou M, Zhang Y, Li B, et al. Complexity Correlation-Based CTU-Level Rate Control with Direction Selection for HEVC [J]. Acm Transactions on Multimedia Computing Communications & Applications, 2017, 13(4):1-23.

[8] Sullivan, G. J., Wiegand, et al. Rate-distortion optimization for video compression [J]. Signal Processing Magazine, IEEE, 1998, 15(6):74-90.

[9] L. Li, B. Li, H. Li and C. W. Chen, "λ -Domain Optimal Bit Allocation Algorithm for High Efficiency Video Coding," in IEEE Transactions on Circuits and Systems for Video Technology, vol. 28, no. 1, pp. 130-142, Jan. 2018.