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Inter-frame Correlation Based Quantization Parameter Offset Optimization for Screen Content Video Coding

Juanting Fan, Shanshe Wang, Shiqi Wang, Ruiqin Xiong, Siwei Ma
Institute of Digital Media
Peking University
Beijing, China
{jtfan, sswang, sqwang, rqxiong, swma}@jdl.ac.cn

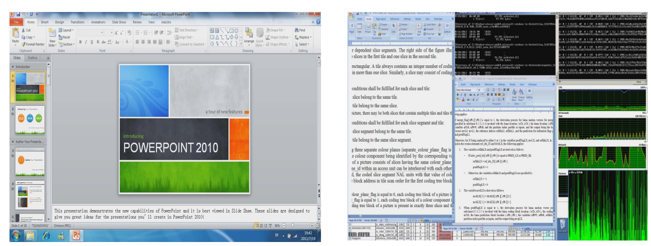
***Abstract*—In this paper, we propose a novel quantization parameter offset optimization scheme for screen content videos based on the high correlation among adjacent frames. Firstly, we define a measurement of inter-frame correlation for successive frames. Then, according to the defined correlation measurement, quantization parameter offset for different frames is appropriately adjusted. Experimental results demonstrate that the proposed optimization scheme brings coding performance improvement. The maximum BD-rate gain can be over 3.8% and the average performance gain is over 2% compared with the reference software.**

Keywords-Screen Content Coding; Quantization Parameter Offset;Inter-frame similarity

I. INTRODUCTION

With the rapid development of electronic devices and high increasing people's need, screen content videos have become more and more popular, such as remote desktop, desktop sharing, video conferencing, game video, demo recording, remote education and so on, as shown in Fig. 1. In the past few years, the amount of the screen content video increases rapidly which makes the compression for screen content videos a hot research topic. The state of the art video coding standard, High Efficiency Video Coding (HEVC) developed by the Joint Collaborative Team on Video Coding (JCT-VC) of ISO/IEC MPEG and ITU-T, has greatly improved the coding performance compared to the previous video coding standards [1]. It provides about 50% bit rate reduction compared to its predecessor H.264/AVC for natural camera-captured videos [2]. However, for screen content videos, the coding performance improvement is not so much due to the specific characteristics of screen content. On this occasion, JCT-VC expands an extension HEVC version named Screen Content Coding (SCC), focusing on investigating new techniques to improve the coding performance for screen content videos. In the past researches, plenty of new techniques are adopted in HEVC-SCC extension to improve the screen content video compression efficiency.

Based on the observation that the content of different regions in a frame is almost the same, Intra Block Copy (IntraBC) is adopted to improve the intra coding performance [3]. It is stated that a range of 2% to 44% bit rate saving can be achieved for different sequences by exploiting IntraBC. However, much coding complexity is brought in. In order to reduce the coding complexity brought by intraBC, some optimization schemes are proposed [4]-[6]. To resolve the complexity issues, [4] limits the effective range of reference block used by IntraBC, and restrict its motion vector to be 1-D (one-dimension) integer-pel. According to those important simplifications, three fast encoding optimized techniques are provided for early skipping of IntraBC search in [5]. The coding complexity can be reduced by about 21%-24% with negligible performance loss. In [6], based on high efficient prediction brought by IntraBC, an adaptive transform skip mode is proposed to skip the transform process for intra block copy predicted blocks in order to reduce the IntraBC computational complexity.



(a) (b)

Figure 1. Screen contents in different application senerios. (a) Remote education. (b) Desktop sharing.

Another adopted essential technology in HEVC-extension for screen content videos is palette coding, known as Base Color Index Map (BCIM). It can be attributed to that the screen content typically contains a limited number of distinct colors as usual. The main purpose of BCIM is to convert the original image block to a block of map indices by applying palette or the derived color mapping table instead. Thus, the dynamic range can be reduced and much performance improvement can be obtained [7][8].

Apart from the above techniques, quantization optimization is developed as well. In [9] and [10], adaptive quantization schemes are proposed to detect specific edge regions in screen content videos or used to chroma component compression creatively.

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These newly adopted technologies bring great coding performance improvement since the specific characteristics of screen content videos are fully considered.

However, hierarchical quantization parameter (QP) offset scheme adopted by HEVC is unchanged as illustrated in Fig. 2. Since the inter-frame correlation among adjacent frames in screen content videos is very high, it is not suitable to adopt the original scheme directly. In this paper, we propose a QP offset optimization scheme for screen content video coding. Based in the high correlation among adjacent frames, QP for different frames can be adjusted adaptively. Thus, performance improvement can be expected.

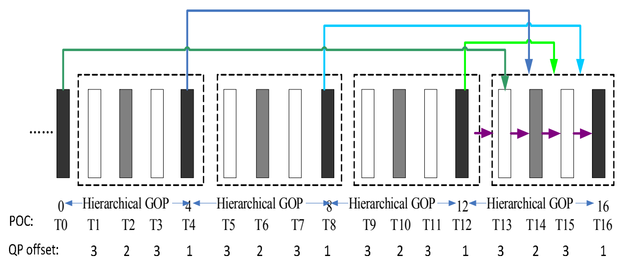

Figure 2. Determination for frame-level QP offset under Low Delay B main SCC configurations.

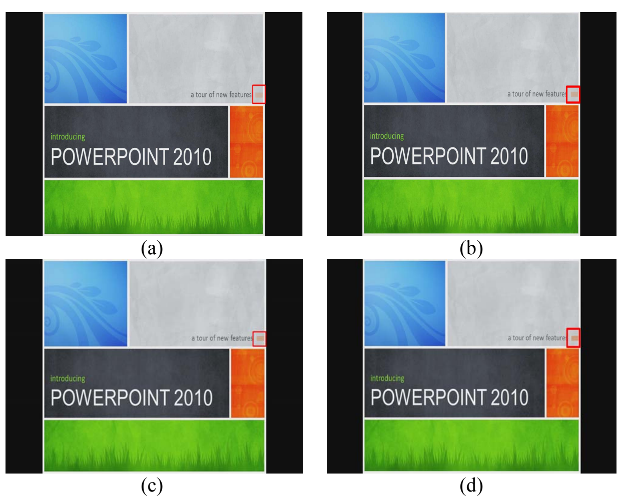

Figure 3. Description of the similarity for screen content video. (a) POC = 14. (b) POC = 15. (c) POC = 16. (d) POC = 17.

The rest of this paper is organized as below. In section II, the proposed optimization scheme is depicted. And the experimental results are provided in section III. Finally, we conclude the paper in section IV.

II. Proposed Inter-frame Correlation Based Quantization Parameter Offset Optimization

In this section, the proposed QP offset optimization scheme is detailed in the following two aspects. First, the inter-frame correlation is defined based on the temporal characteristics. Then, the adaptive adjustment scheme for the QP offset is provided based on inter-frame correlation.

A. The Definition of Inter-frame Correlation for Screen Content Videos

Screen content videos have its own special characteristics. Successive frames played in specific scenarios are always changing gradually. Therefore, there exists high inter-frame correlation among successive frames. Especially, some successive frames in a sequence are almost the same. Fig. 3 shows four successive frames whose Picture Order Count (POC) values from 14 to 17 for 720p YUV444 *SlideShow*. It can be seen that there is little difference among these successive frames. Only a small range of content denoted by a red box is different. In this paper, we use inter-frame correlation (IFC) to evaluate the similarity between the two successive frames. The definition of IFC is detailed as follows.

Firstly, the two successive frames, including current frame that is under compressed and previous frame that has been already reconstructed, are splitting into non-overlapped $N\times N$ blocks, as shown in (1), where FP indicates the previous reconstructed frame and FC indicates the current encoding frame, C_i represents for the i^{th} $N\times N$ block in current frame, counted by raster scanning, and P_i represents for the i^{th} $N\times N$ block for the previous reconstructed frame, and N_{total} is the total number of $N\times N$ blocks in a frame decided by its width and height, as shown in (2), where $Width_f$ and $Height_f$ indicate the width and height of the frame.

$$FC=\sum_{i=0}^{N_{total}} C_i, \quad FP=\sum_{i=0}^{N_{total}} P_i. \tag{1}$$

$$N_{total}=(\frac{Width_f}{N}+1)\times(\frac{Height_f}{N}+1). \tag{2}$$

Secondly, the Sum of Absolute Difference (SAD) of the two corresponding blocks, defined as C_i and P_i, will be calculated. If SAD is smaller than the threshold, the two collocated blocks will be regarded as Similar Blocks (SB). Meanwhile, the parameter N_{corr} which is utilized to count the number of SB for these two frames should add 1.

When all the SBs have been already processed, the final N_{corr} will be figured out with (3) and (4), and the inter-frame correlation will be calculated according to (5).

$$N_{corr}=\sum_{i=0}^{N_{total}} N_i. \tag{3}$$

$$N_i=\begin{cases} 0, & if \left\| \sum_{j=0}^{N\times N} C_{i,j} - \sum_{j=0}^{N\times N} P_{i,j} \right\|_{SAD} < Threshold \ is \ true \\ 1, & else. \end{cases} \tag{4}$$

$$\delta_{corr}=\frac{N_{corr}}{N_{total}}. \tag{5}$$

where δ_{corr} is the value of IFC, and N_i indicates whether the two blocks, P_i and C_i, are SBs or not, after calculating SAD, and $P_{i,j}$ indicates the j^{th} pixel in P_i, so as to $C_{i,j}$. And the bigger δ_{corr} is, the more similar these two successive frames will be. Fig. 4 displays the whole process of this IFC scheme.

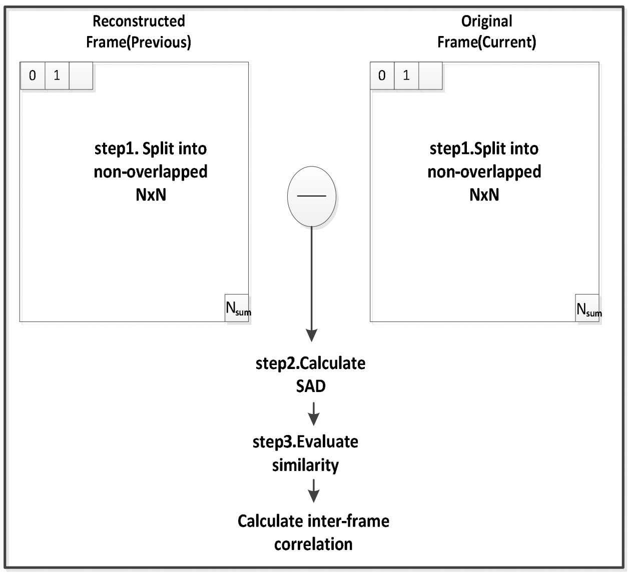

Figure 4. The whole process of IFC calculation.

For the IFC, the threshold in (4) has much influence on the final performance. In order to achieve an optimal threshold when computing the IFC, we apply a set of values as the threshold to calculate the δ_{corr}, as shown in Fig. 5.

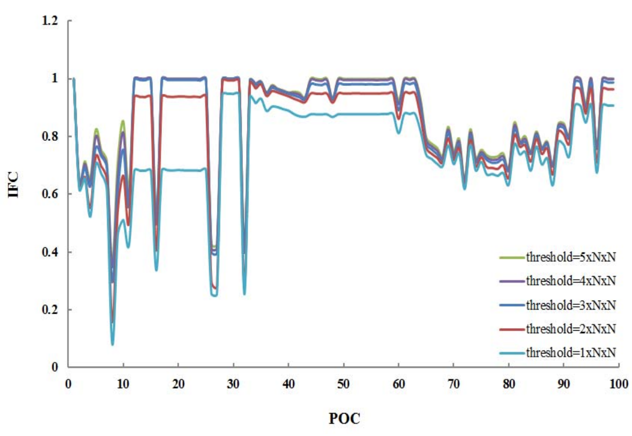

Figure 5. Relationship between IFC and threshold.

From the statistical results, it can be observed that δ_{corr} is related to threshold, but the relevance between them is not strong. That is because the successive frames remain almost the same in particular scenarios. As a consequence, we regard $5\times N\times N$ as the threshold and N equals to 16.

B. Proposed Scheme for Quantization Parameter Offset

In this subsection, based on the δ_{corr} decided by IFC, a QP offset adjustment scheme is proposed to adaptively adjust the QP offset, in order to improve the coding performance.

As illustrated in Fig. 1, the QP offset of the frame is determined by the level of the frame, as described in Table I. If a frame is at the low level (such as POC *T4*, *T8*, *T12*), that means it will be referenced for much more times than others, and it is essential to keep its reconstructed quality so that its QP offset would like to be smaller. The *GOP_SIZE* in Table I indicates the size of GOP and equals to 4.

Under this circumstance, we make a delta QP offset decision according to the level of the frame, as showed in Table II. And the final quantization parameter can be represented as the following.

$$QP = QP_{base} + Offset_{anchor} \pm Offset_{\Delta},$$
$$Offset_{\Delta} = \Delta_{POC\%GOP\_SIZE}. \qquad (6)$$

where QP_{base} and $Offset_{anchor}$ are set as the same in default configurations. *GOP_SIZE* equals to 4, and $Offset_{\Delta}$ is derived from Table II.

TABLE I. DETERMINATIONS FOR THE VALUE OF FRAMES' LEVEL

POC%GOP_SIZE	1	2	3	0
Level	0	1	0	2

TABLE II. QP OFFSET DECISION UNDER HIERARCHICAL B CONFIGURATIONS (Δ_1>Δ_2>Δ_3)

POC%GOP_SIZE	1	2	3	0
***Offset**$_{anchor}$*	3	2	3	1
Δ	Δ_1	Δ_2	Δ_1	Δ_3

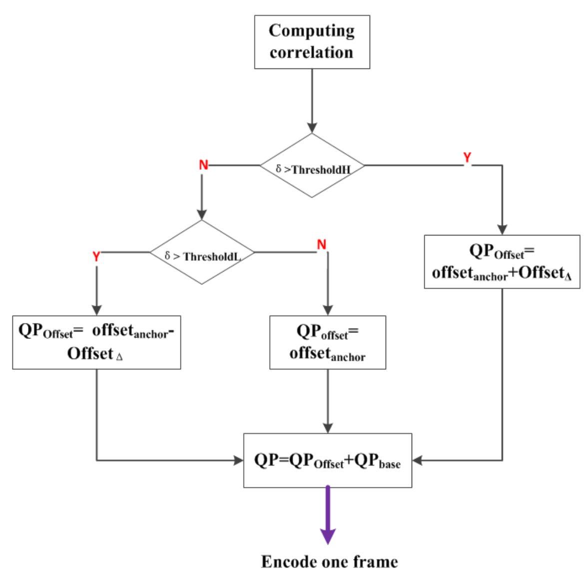

Figure 6. The flowchart for proposed QP decision scheme.

Under the common test conditions [11], several QP_{base} will be used for obtaining different-level compressive ratio. The larger QP_{base} is, the higher the compressive ratio is. Thus, it is improper to use the same $offset_{\Delta}$ for all QP_{base}. In this paper, Δ_i is determined as different values for different QP_{base}, as shown in (7).

$$\Delta_i = \begin{cases} i-1, & if\ QP_{base} = 22\ or\ 27, \\ i, & if\ QP_{base} = 32\ or\ 37. \end{cases} \quad (7)$$

Eventually, after evaluating the value of IFC, the whole scheme flowchart can be described in Fig. 6. In the proposed scheme, *ThresholdH* and *ThresholdL* are two thresholds depend on experimental statistics and are set to 0.95 and 0.5, respectively.

III. Experimental Results

The proposed inter-frame correlation based QP offset optimization scheme has been implemented on top of HM16.2+SCM3.0 [12]. The testing configuration is low delay main common test conditions, and all the tested sequences have full chroma [11]. To evaluate the R-D (Rate-Distortion) performance, several screen content sequences in a variety of resolutions as illustrate in Table III, are coded. The base QP is set as default in HEVC reference software.

TABLE III. BD-Rate gain for screen content sequences using proposed method, comparison to anchor.

Sequence	Resolution	BD-rate		
		G/Y	B/U	R/V
Programming	720p, RGB	-1.93%	-1.31%	-2.39%
SlideShow	720p, RGB	-1.34%	-1.68%	-1.48%
BasketballScreen	2k, RGB	-3.39%	-3.22%	-2.85%
MissionControlClip2	2k, RGB	-2.41%	-2.76%	-2.29%
MissionControlClip3	1080p, RGB	-1.09%	-0.76%	-0.65%
Programming	720p, YUV	-3.84%	-3.44%	-6.01%
SlideShow	720p, YUV	-1.93%	-3.56%	-2.26%
BasketballScreen	2k, YUV	-2.90%	-3.15%	-2.82%
MissionControlClip2	2k, YUV	-2.34%	-1.62%	-1.90%
MissionControlClip3	1080p, YUV	-1.01%	-1.14%	-1.47%
Average		**-2.02%**	**-2.06%**	**-2.19%**

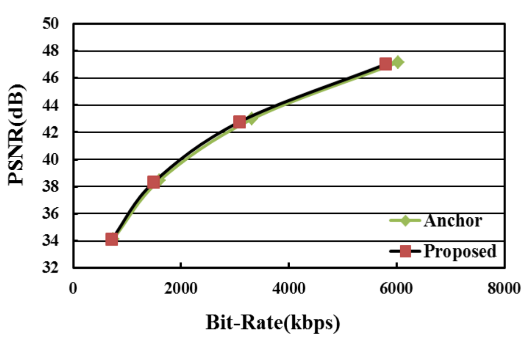

Figure 7. Comparison of RD curves for proposed method and anchor.

The experimental results are summarized in Table III. A negative change in BD-rate indicates improvement in compression efficiency of the tested method over the reference [11]. This IFC based QP offset optimization scheme achieves an average BD-rate gain of -2.02%, -2.06%, -2.19% for Y, U, V (or G, B, R) component respectively.

From Table III, it can be seen that the proposed optimization scheme can significantly improve the rate distortion performance. The maximum coding gain can be over 3.84%. Fig. 7 shows the comparison of rate distortion curve between the proposed scheme and HM16.2+SCM3.0 anchor for *Programming*. It can be observed that the proposed scheme can obtain better R-D performance under different bit rate.

IV. Conclusion

This paper proposes a novel QP offset optimization scheme in order to improve the performance improvement for screen video coding. Based on the defined inter frame correlation, QP offset can be adaptively adjusted. Experimental results demonstrate that the proposed scheme can significantly improve the coding performance compared with the original HM reference software.

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