HEVC 영상압축을 위한 적응적 스칼라 양자화

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Adaptive Scalar Quantization for HEVC Video Coding

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요 약

This paper introduces an adaptive scalar quantization scheme for video coding technology. The method utilizes the property of the coefficient groups (CG) inside each transform block so that the dead-zone interval of the scalar quantizer is adaptively set up for different CGs. Its experimental results show that our proposed quantization scheme can achieve BDBR reduction of 4.75%, 5.93, and 5.16% for Y, Cb, and Cr channel respectively when encoding with HEVC.

1. Introduction

Video coding techniques have become more essential in broadcasting area since the high-resolution video contents demand much better coding tools which can provide a higher compression efficiency. To meet this requirement, researchers keep trying to develop more advanced video coding techniques such as High Efficiency Video Coding (H.265/MPEG HEVC) [1]. It is claimed that HEVC achieves approximately 50% of bit-rate reduction with the same quality compared with the previous generation standard like H.264/MPEG AVC [2].

Compared with other coding tools, quantization technique provides considerable bit-rate reduction in lossy compression. Scalar quantization (SQ) is applied to HEVC encoder, and a rate distortion optimized quantization (RDOQ) technique can be switched on to further improve the quantization performance by making a tradeoff between bit-rate and distortion. RDOQ technique can provide large coding gain, however, it consumes huge computation to estimate and compare the rate and distortion. Therefore, it is meaningful to improve a conventional SQ that can approximate RDOQ performance with a much lower time complexity. Many researchers have investigated on simplifying the RDOQ process. For example, a quantization round offset lookup table is suggested to replace the level estimation process in RDOQ [3] which can significantly save the quantization time.

This paper proposes an adaptive quantization scheme which adjusts the dead-zone of SQ based on the slice type and the property of coefficient groups (CG) inside each transform block (TB).

2. Quantization Scheme in HEVC

HEVC calculates the SQ level l_{SQ} as the input of RDOQ process as below:

$$l_{SQ} = \lfloor \frac{|c|}{\Delta q} + \theta \rfloor, \quad (1)$$

where c denotes the coefficient after transform, Δq is the quantization step size, and θ represents the round offset which is set to 1/2.

The RDOQ process then goes through three internal steps (level estimation, all zero CG determination, and last significant coefficient determination) to find out the optimum quantized levels for each coefficient.

3. Proposed Adaptive Scalar Quantization

To better approximate the output of RDOQ process behavior, we carried out a statistical analysis on the properties of each CG inside TB to understand more about the RDOQ behavior. The data used for analysis are generated from 32 frames of sequence BasketballDrive encoded under random access (RA-Main) coding configuration with quantization parameter (QP) of 22 and 32. We calculate the sum of nonzero quantized levels inside each CG after SQ and RDOQ (denote as sum_{SQ} and sum_{RDOQ}, respectively).

Figure 1 shows sum_{SQ} and sum_{RDOQ} of each CG inside four different TB sizes (4×4, 8×8, 16×16, and 32×32) in I-Slice (first frame), from where we can observe that when $sum_{SQ} \leq 3$, sum_{RDOQ} tends to be zero. This observation

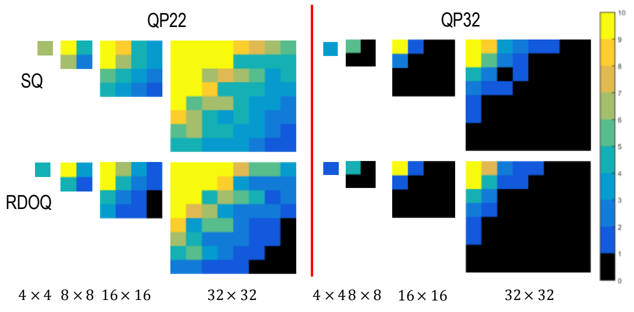

Fig. 1. sum_{SQ} and sum_{RDOQ} in each CG (BasketballDrive, I-Slice, QP22 and 32)

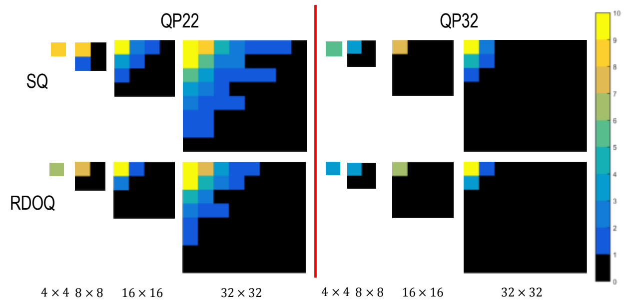

Fig. 2. sum_{SQ} and sum_{RDOQ} in each CG (BasketballDrive, B, P-Slice, QP22 and 32)

indicates that the CG is likely to be optimized to all zero after the RDOQ process. Similarly, Fig. 2 shows sum_{SQ} and sum_{RDOQ} of four TB sizes in B, P-Slice (frame 2-32). It shows that sum_{RDOQ} tends to become zero when $sum_{SQ} \leq 2$. In order to better imitate the output optimized level after RDOQ process, the observations from the above analysis motivates us to setup a larger quantization dead-zone when the CG is likely to become all zero after RDOQ process.

In this work, we propose to calculate the quantized level l_{SQ}^{*} with an adaptive dead-zone ranging from 0 to $Thres$:

$$l_{SQ}^{*} = \begin{cases} 0 & when\ |c| \leq Thres \\ \lfloor \frac{|c|}{\Delta q} + \frac{1}{2} \rfloor & otherwise \end{cases} , \quad (2)$$

where $Thres$ is determined based on slice type and sum_{SQ} of each CG.

$$Thres = \begin{cases} \frac{5}{6} & when\ sum_{SQ} \leq 2\ \ (I - Slice) || \ sum \leq 3\ (B, P - Slice) \\ \frac{2}{3} & other\ wise \end{cases} . (3)$$

Moreover, the CGs with the DC coefficient will always use 2/3 as the threshold to better keep the low frequency components.

3. Experimental Results

To evaluate the performance of our proposed quantization scheme, the experiments are done using HEVC reference software HM 16.15 [4] with RDOQ tool disabled (RDOQ-Off).

Table 1. BDBR (%) Comparison of the Proposed Method with Anchor (RA-Main)

Sequences		Y	Cb	Cr
Class B	Kimono	-7.26	-6.40	-4.64
	ParkScene	-3.43	-4.19	-2.18
	Cactus	-5.66	-4.40	-8.16
	BasketballDrive	-5.32	-10.73	-11.60
	BQTerrace	-2.07	-1.91	-0.78
Average		**-4.75**	**-5.93**	**-5.16**

Five sequences are tested under RA-Main coding configuration, and four QP values (22, 27, 32, and 37) are used following the common test condition [5]. The Bjontegaard Delta Bit-Rate (BDBR) is utilized to evaluate the coding performance of the proposed method against original HEVC scalar quantization with RDOQ-Off as the anchor. The BDBR performance is illustrated in Table 1, from where we can see the proposed adaptive scalar quantization scheme achieves 4.75%, 5.93, and 5.16% BDBR gain for Y, Cb, and Cr channel, respectively.

4. Conclusion

An adaptive scalar quantization scheme for video coding is addressed in this paper. The proposed method adaptively adjust the dead-zone interval based on the sum of the transform coefficients of each CG inside each transform block. The experiments are carried out using HEVC reference software, and the test results show that the proposed quantization scheme provides 4.75%, 5.93%, and 5.16% gain in BDBR for Y, Cb, and Cr channel, respectively.

References

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