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Detection for All Zero Coefficient Blocks in HEVC Based on Uniform Quantizer

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Abstract. Transform and quantization are adopted in HEVC. There are lots of all zero coefficient blocks in transform and quantization. By detecting all zero coefficient blocks, the complexity of transform or quantization can be greatly reduced. All zero coefficient blocks for uniform quantizer can be efficiently detected by comparing the float quantization level of the estimated coefficients with an explicit threshold. The experimental result shows that 50% complexity of transform or quantization for uniform quantizer can be reduced with negligible loss of video coding efficiency.

Keywords. HEVC, all zero coefficient blocks, uniform quantization, RDO quantization, SATD

1. Introduction

High Efficiency Video Coding (HEVC) is the new video coding standard developed by JCT-VC [1]. HEVC provides better compression performance than H.264/AVC [2]. Several new techniques are included in HEVC, such as Rate Distortion Optimized Quantization (RDOQ), Sample Adaptive Offset (SAO), Coding Tree Unites (CTU).

Transform and quantization are the most computational parts in HEVC [3]. The basic unit for transform and quantization in HEVC is called transform block (TB). Skipping all zero coefficient blocks can reduce the coding complexity of transform and quantization, as well as the prediction mode decision and advanced motion vector prediction [4].

There are many proposed detection algorithms for all zero coefficient blocks in H.264/AVC. An early predicting all zero coefficients is proposed in [5], and the threshold can be changed with the quantization level. A hybrid model was proposed in [6] to predict zero quantized Discrete Cosine Transform (DCT) coefficients with Gaussian distribution and optimized efficient condition to detect all zero DCT blocks. To get more frequency characteristics, Xie presents a mathematic model by analysing DCT for detecting all zero coefficient blocks [7].

The above algorithms mainly focused on detecting all zero coefficient blocks by mathematic models without considering uniform quantizer (UQ). In this paper, the

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detecting all zero coefficient blocks algorithm for UQ is proposed. And the proposed algorithm is based on determining the quantization level (QL) for the global maximum magnitude (MM). The estimated global MM is used to detect all zero coefficient blocks (AZCB) and non-all zero coefficient blocks (non-AZCB). As a result, AZCB can be easily detected by comparing the float QL (FQL) of the estimated coefficients with the threshold.

2. Transform and Quantization in HEVC

The HEVC standard specifies integer DCT matrices of size 4×4, 8×8, 16×16 and 32×32 to be used for two-dimensional transforms in the context of block-based motion-compensated video compression. For the 4×4 transform of luma intra picture prediction residuals, an integer discrete sine transform (DST) is alternatively specified. In addition, transform skip is also introduced in HEVC to improve compression ratio of screen-content video sequences generated in applications such as remote desktop, slideshows etc. When transform skip mode is used, prediction residuals are quantized directly. Transform skip mode is restricted to only 4×4 transform blocks. DST is regarded as a special DCT, and transform skip is regarded as a special transform.

By supposing the transform of HEVC encoder is orthonormal in this paper, UQ can be calculated as,

$$l_i^{uq} = floor\left(\frac{|c_i|}{Q_{step}} + offset\right) \quad (1)$$

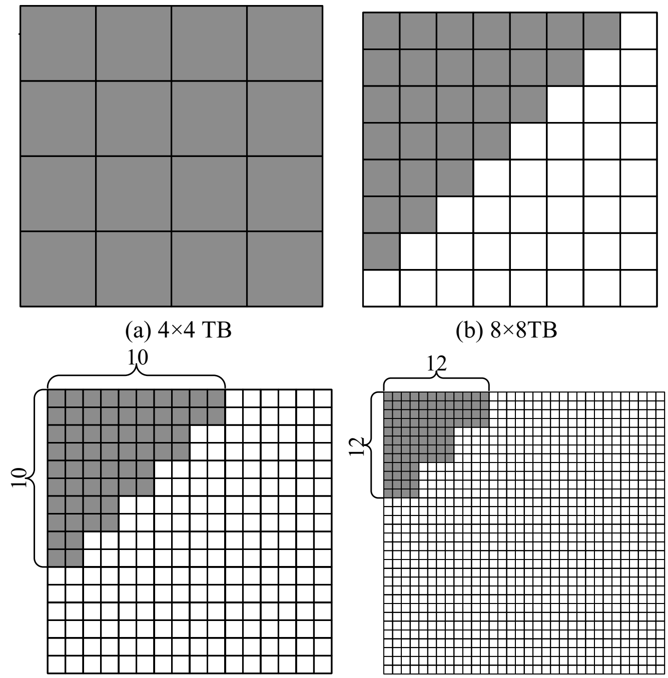
where c_i is transform coefficient, l_i^{uq} is the QL of c_i, and Q_{step} is the step of quantization. The offset depends on the slice type, for I slices the offset equals 1/3 and for non-I slices it is 1/6.

3. DCT Coefficients Estimation

Zero mean Gaussian distribution model is used in this paper to get the distribution of prediction residuals. Then, the distribution of DCT coefficients can be calculated. The standard deviation of DCT coefficients are used to estimate the global MM.

DCT coefficients are estimated twice in the original method. The proposed method use transform coefficients estimation based on the feature of DCT energy concentration. As Figure 1 shows, in the DCT process, prediction residuals are concentrated with more low frequency coefficients, low frequency coefficients have higher impacts to the coding units than high frequency coefficients. So, we should focus on high frequency coefficients.

There is a threshold of high frequency coefficients and low frequency coefficients. From the classification result shows in Figure 1, coefficients in 4×4 TB are all selected as low frequency coefficients. But for 8×8, 16×16 and 32×32 TBs, only part coefficients are selected as low frequency coefficients and most of them are gathered at the left-top of the coding units.



(a) 4×4 TB (b) 8×8TB (c) 16×16 TB (d) 32×32 TB

Figure 1. The selected low frequency coefficients

4. AZCB detection in HEVC

The limit between QL equals zero and non-zero is explicit for UQ. And FQL can be defined as,

$$l_i^{float} = \frac{|c_i|}{Q_{step}} \qquad (2)$$

Comparing (1) and (2), it can be found that l_i^{float} is just the float style of l_i^{uq}. What is more, if l_i^{float} is less than (1 - *offset*), l_i^{uq} equals to zero. Set *Th_U* = (1 – *offset*), then *Th_U* can be used as the threshold between QL equals zero and non-zero. If *Th_U* is larger than FQL of every coefficient in a TB, AZCB can be determined. Therefore, the FQL of the estimated low frequency coefficients and HM_{est} should be compared with *Th_U* one by one until AZCB or non-AZCB can be determined. But it is found that the accuracy of AZCB detection is sensitive to the MM of the estimated low frequency coefficients. The estimated low frequency coefficients (HT coefficients) are amplified a bit before AZCB detection to prevent the misclassification of the non-AZCB.

The scaling factor is calculated as,

$$\alpha_N = \underset{u,v \in LF}{\text{mean}}(\sigma_{D/H}(u,v)), \sigma_{D/H}(u,v) > 1 \qquad (3)$$

where *LF* is the location set of the selected low frequency coefficients, *N* is the size of TB and $\sigma_{D/H} = \sigma_D / \sigma_H$. σ_D and σ_H are the standard deviation of DCT coefficients and the standard deviation of HT coefficients respectively. These two parameters can be obtained by replacing D by DCT or HT. Then, the estimated low frequency DCT coefficient is,

$$L_{est,N}(u,v) = \alpha_N \cdot B_N(u,v), \quad u,v \in LF \qquad (4)$$

Besides, the global MM can also be used to pre-detect AZCB. It is obvious that if the QL of the global MM is zero, the QLs of other coefficients must be zero. Therefore, AZCB can be easily determined by comparing the FQL of the global MM with *Th_U*. If the FQL of the global MM is less than *Th_U*, AZCB can be determined. The estimated global MM is also used to skip coefficients estimation when non-AZCB occurs. The threshold in this paper is assigned to be 1.3 for SAD and 1.9 for SATD. If the FQL of the estimated global MM is larger than the defined threshold, denoted by *Th_skip*, the TB is considered as a non-AZCB, and coefficients estimation will be skipped.

The flowchart of AZCB detection in UQ is shown in Figure 2. At first, the global MM of DCT coefficients is estimated and its FQL is compared with *Th_U*. If *Th_U* is larger than the FQL, AZCB is determined; if not the FQL will be compared with *Th_skip* to determine non-AZCB. If AZCB or non-AZCB cannot be determined, then low frequency coefficient $L_{est,N}(u,v)$ is estimated and the corresponding FQL is compared with *Th_U* one by one to determine non-AZCB. If non-AZCB cannot be determined by low frequency coefficients, the MM of high frequency coefficients HM_{est} will be calculated and its FQL is compared with *Th_U*. If *Th_U* is larger than the FQL, the corresponding TB is an AZCB, if not it is a non-AZCB.

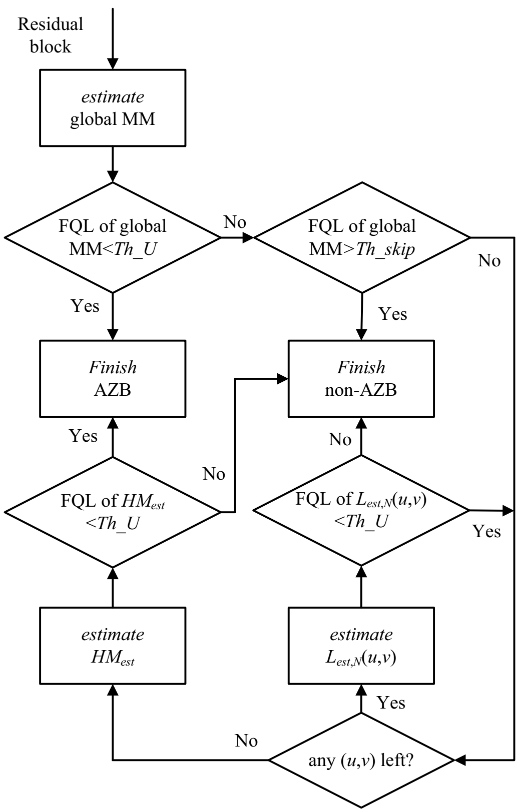


Figure 2. The flowchart of AZCB detection in UQ

5. Experimental results

The following experimental results are based on HEVC test model version 13.0 (HM 13.0). The standard encoder_lowdelay_main.cfg configuration file is used. 21 typical test sequences are selected from Class A to Class F, with the quantization parameters (QP) set to 22, 27, 32, and 37 respectively. The change of BDPSNR, BDBR [8], and coding time are shown on Table 1. As Table 1 shows the average time saving of the proposed method is 50%. The proposed method can greatly reduce coding efficiency with a negligible loss of PSNR and BD-rate.

Table 1. The Results for UQ AZCB Detection

Sequence	BDBR (%)	BDPSNR (dB)	TS (%)
PeopleOnStreet	-0.04	0.002	44
Traffic	-0.15	0.005	50
BasketballDrive	0.09	0.000	44
BQTerrace	-0.07	0.001	51
Cactus	-0.09	0.002	48
Kimono	-0.07	0.002	42
ParkScene	0.03	-0.001	53
BasketballDrill	0.09	-0.004	49
BQMall	-0.06	0.003	44
PartyScene	-0.03	0.002	41
RaceHorsesC	-0.05	0.002	36
BasketballPass	0.00	-0.001	43
BlowingBubbles	0.14	-0.005	41
BQSquare	0.13	-0.005	50
RaceHorsesD	0.02	-0.002	36
FourPeople	0.11	-0.006	64
Johnny	-0.04	-0.001	69
KristenAndSara	0.12	-0.003	65
ChinaSpeed	-0.09	0.005	51
SlideEditing	-0.07	0.010	69
SlideShow	0.10	-0.007	63
Average	0.00	0.000	50

The accuracy of AZCB detection process can be measured by false acceptance ration (FAR) and false rejection ratio (FRR). They can be calculated as equation (5),

$$FRR = \frac{num_{mz}}{num_z} \qquad FAR = \frac{num_{mn}}{num_n} \tag{5}$$

The num_{mz} means the number of AZCB which are classified as non-AZCB incorrectly, and num_z represents the real number of AZCB. While num_{mn} and num_n represent the number of non-AZCB which is misclassified as AZCB and the real number of non-AZCB. FRR means the ratio of AZCB which are classified as non-AZCB incorrectly, while FAR means the ratio of non-AZCB misclassified as AZCB. We want to detect AZCB as much as possible, which means that the FRR and FAR will be very low. In other words, higher detection efficiency means lower FRR and FAR.

Table 2. Detection Efficiency in UQ by the Proposed Algorithm(FRR)

Sequence	4×4 FRR (%)	8×8 FRR (%)	16×16 FRR (%)	32×32 FRR (%)
Class A	1.2	3.2	5.2	13.7
Class B	1.8	3.5	5.5	12.2
Class C	2.8	6.2	9.2	19.0
Class D	2.1	7.1	10.4	20.5
Class E	1.0	2.4	3.4	7.2
Class F	1.1	3.0	4.4	7.0
Average	1.7	4.2	6.4	13.3

The results of the proposed algorithm for UQ are shown as Table2 and Table3. The average FRR of 4×4, 8×8, 16×16 and 32×32 TBs are 1.7%, 4.2%, 6.4% and 13.3% respectively. The average FRR of 4×4, 8×8, 16×16 and 32×32 TBs are 2.9%, 4.1%, 6.8% and 5.8% respectively.

Table 3. Detection Efficiency in UQ by the Proposed Algorithm(FAR)

Sequence	4×4 FAR (%)	8×8 FAR (%)	16×16 FAR (%)	32×32 FAR (%)
Class A	3.0	4.3	6.5	4.0
Class B	3.0	4.4	7.0	6.3
Class C	2.4	3.4	5.0	3.4
Class D	3.2	4.4	6.1	5.0
Class E	3.2	5.2	10.5	10.8
Class F	2.3	3.1	6.2	5.7
Average	2.9	4.1	6.8	5.8

Figure 3 compared the frame for both the proposed AZCB algorithm and the original HM test model. There are no notable differences between these images.

Figure 3. frame of proposed algorithm and HM

6. Conclusion

An AZCB detection algorithm for UQ is proposed in this paper. The algorithm adopts a low and high frequency coefficients separation strategy to estimate transform coefficients. Threshold to determine AZCB in UQ can be deduced directly. The proposed algorithms are implemented on HEVC test model to verify the efficiency. Experiment results show that the proposed algorithm can efficiently reduce the computation complexity while keeping nearly the same RD performance as with the original algorithm in HEVC.

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