Adjustment of Offset Value for Reduction of Complexity in HEVC Intra Mode

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***Abstract*— In this paper, we propose a complexity reduction method of sample adaptive offset (SAO), which is an in-loop filter in high-efficiency video coding (HEVC). In the conventional SAO, an offset value is calculated for each coding tree block (CTB) to minimize the error between the original and reconstructed images. In order to determine the optimal offset value, all offset candidates are examined and the offset value that leads to the smallest rate-distortion cost is chosen. Thus, SAO occupies a significant amount of the computational complexity in the HEVC encoder. In the proposed method, we determine the least-used band (LUB) by considering the statistical characteristics of offset values and without processing the offset value included in the LUB. Also, in the offset value decision stage, we check only a certain number of candidates rather than all of them. Experimental results show that the proposed method reduces the encoding time by approximately 8.15% without yielding a significant loss in terms of coding efficiency.**

Keywords— HEVC, SAO, BO, In-loop filter

I. INTRODUCTION

Recently digital broadcast technology and the development of display devices are improved so, consumer's demand for high-resolution video and a various video contents are increased. Before long the existing size of the image like UHD (Ultra High Definition) and ultra-high-resolution images contents will be replaced with new one [1]. Ultra-high-resolution video contents are used in many different type of filed. High-resolution images need a compression technique to send or save the amount of data efficiently. As a result of necessity of data compression, we need more effective video codec standard technique over the H.264/AVC compression efficiency [2]. In Jan. 2013 the HEVC video compression standard codec is completed by VCEG (Video Coding Experts Group) and MPEG (Moving Picture Experts Group). Difference with the previous standard H.264/AVC, HEVC uses two type of in-loop filter that is deblocking filter and SAO (Sample Adaptive Offset).

In-loop filter can correct the quantization error. Quantization error occurred while performing the quantization procedure. Because QP interrupt when the original image convert to frequency domain, so the data loss occur. And also in-loop filter increase the subjective and objective image quality. To improve the prediction efficiency, in-loop filter use a filtered picture as an inter-predict reference image. On the other hand post filter did not use the filtered picture as a reference image [3]. In HEVC apply a deblocking filter at vertical and horizontal direction pixels to compensate the error which occurred in reconstructed image. After the deblocking filter the sample adaptive offset applied to post filter image.

Even HEVC can get a high encoding efficiency by using an in-loop filter, but it also has a high complexity problem. Because HEVC use two different in-loop filter type. In case of applying the SAO BO (Band Offset), to find an optimal offset value we have to calculate the distortion and cost value about all of 32 bands. After calculating all of each bands and lastly compare each band distortion and cost value. In this process there need a lot of calculation procedure. Because of those reason, one kind of in-loopfilter SAO increase the time complexity. To solve this problem we propose the method that improve the encoding processing speed with an in-loop filter performance.

II. SAMPLE ADAPTIVE OFFSET

A. Structure of Sample Adaptive Offset

In encoding process quantization make a data loss different to other function in encoder. The loss come from the quantization which can change the original image value larger or smaller. This type of error called quantization error. SAO calculate the proper offset values, and compensate the quantization error by using those values. SAO is not used in H.264/AVC video compress standard codec, but it proposed when make a HEVC in-loop filter standard. SAO has a merit in high compress efficiency compare to its own complexity. SAO use one of type in three different filter type. This type of filter chart is shown in table 1. If SAO filter don't have to use in current pixel then, choose 0 type. Type 1 use BO(band offset) which in SAO filter. And type 2 use EO(edge offset) which also in SAO filter. BO show the most efficient when specific luminance values compare to original pixel luminance values has difference. If some pixels are parts of in BO then, BO determine the offset value to compensate the error occurred in encoding procedure. EO is effective method when current pixel data has an edge information. So EO is used in frequently, because in picture there are many edge information and objects can be presented by using an edge.

Before introduce the proposed method, explain more about the BO.

TABLE I. SAO FILTER TYPE

Index	SAO type
0	Not use SAO
1	Band Offset
2	Edge Offset

B. Band Offset

BO determine the offset value which has similar luminance pixel value group. And by adding this offset value to specific band, BO can minimize the encoding error [4]. BO divide the similar luminance in consecutive four bands. As like the decoder, an offset value is added in the same encoding luminance band number. So decoder can reconstruct the compensated image. Namely the BO minimize the difference between the original and reconstructed image. In encoder divide the pixel luminance value into the 32 different bands like figure 1. Because each band has an 8bit depth luminance value, then total 32 bands have a 0~255 luminance value. The first band has 0~7 pixel value and second band has 8~15 pixel value. In general each band pixel value is 8i~8i+7 where i mean the i th band number.

In BO only added the offset value in consecutive four bands. So when transmit the SAO encoder processing information to decoder, the consecutive four band and the start band number of four band information is essential parts. The start band mean the leftmost band in consecutive four band. While adding the offset value in consecutive four band, compare each of the offset value to find which offset value is the optimal offset value [5]. The optimal offset value is minimize the difference between the original pixel value and reconstructed pixel value. Also different to EO, BO has an encoding information which called flag. So the encoding information have to transmit to decoder.

III. PROPOSED METHOD

A. Band restricted SAO

BO in original HEVC reference software HM11.0 is performed by getting average value of difference between original image pixels and reconstructed image pixels. In this paper by performing examination for 32 band usage frequency and determined the least used band number. Least used band restrict the calculating of offset value. BO divide the luminance value into 32 band and find the smallest cost by changing the start band. In this procedure we have to calculate the addition and product operation to get a rate-distortion cost. Because each of the band performing the many times of adding or product operation which things cause an increasing of complexity.

If all of the cost value calculation is completed then, by comparing each of the cost value and find the smallest offset value. In performing BO, the offset value is added in the first start band. At that time if the offset value is added in some band then count the number which band is used [6].

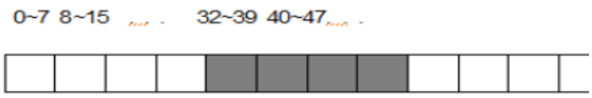

Fig. 1. Example of Band Offset (BO)

To prove the proposed method's performance, use the standard test sequences Class A, B, C and D for each of two. By using those test sequence we can get the LUB (least used band).

The result, getting from the test sequences is shown in figure 2. In histogram lest used band number 4, 5, 20 and 22 restrict the calculating a rate-distortion cost value. By restricting the calculating operation we can decrease the complexity.

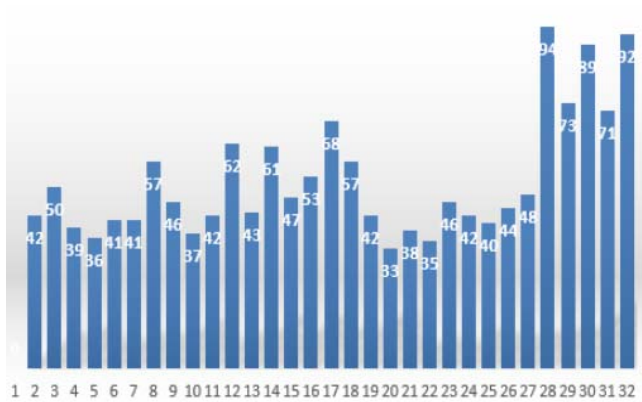

Fig. 2. Frequency of Band Usage

The flow chart of proposed method is shown in figure 3. While processing BO, if the current band is correspond to least used band, then which band did not calculating the offset and cost value. If the current band is not correspond to the least used band, then performing the original band offset procedure.

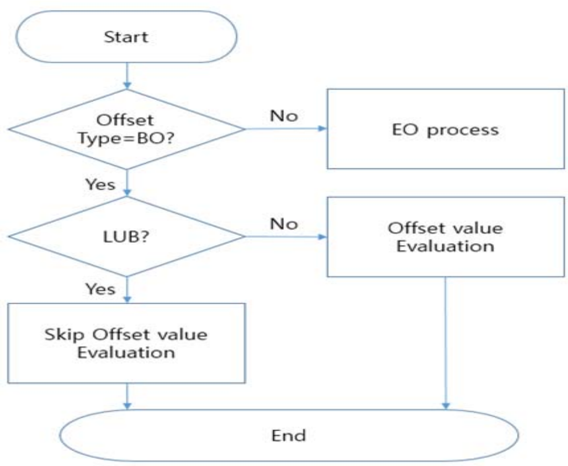

Fig. 3. Band restrict flow chart

B. *Offset size difference finding optimal offset value*

In section 3-A, propose the method which restrict specific band when performing the SAO band offset. However to find the optimal offset value it need to calculate the cost value, while changing the offset value. In this procedure, time complexity increase. Because it calculate the difference of original images and reconstructed images. In this section propose the method which control the offset increase or decrease rate when calculate the cost value. To get an optimal cost value, SAO repeatedly calculate the difference of original images and sampled reconstructed images [7]. If those procedure is repeated many times then, the frequency of memory access increased. So to decrease the frequency of memory access we use the fast distortion estimation method [8].

To calculate the distortion, set the value k, s(k) and x(k) as a sample pixel location, original image sample and reconstructed image sample. Then the distortion between original image and SAO sample image is defined in equation (1).

$$D_{pre} = \sum_{k \in C} (s(k) - x(k))^2 \quad (1)$$

Offset value is presented in equation (2). In this equation the difference of original pixels and reconstructed pixels values are divided by number of pixel where N.

$$\text{Offset} = \frac{\sum_{n=0}^{N-1}(Org_n - Rec_n)}{N} \quad (2)$$

Next equation (3) show the difference of original image and reconstructed image which offset value h is added. Equation show those two image distortion.

$$D_{Post} = \sum_{k \in C} (s(k) - (x(k) + h))^2 \quad (3)$$

In equation (4) explain the process to find a distortion by using an original sample image and sample image which added offset value h. The distortion is used to calculate the cost value for find the optimal offset value.

$$\Delta \mathrm{D} = D_{Post} - D_{Pre} = \sum_{k \in C} \left(h^2 - 2h\big(s(k) - x(k)\big)\right) \quad (4)$$

Summarize the equation (4) then we can get the other form consist of encoding error, pixel group and pixel number like equation (5).

$$\Delta \mathrm{D} = \sum_{k \in C} h^2 - 2h \sum_{k \in C} \big(s(k) - x(k)\big) = Nh^2 - 2hE \quad (5)$$

To find the optimal offset value, changing the offset value h and compare each of the cost value. In equation (5) the value h was target of proposed method. The original h changing rate was 1. But changing this rate 1 to 3, so we can avoid calculation of some offset values. Calculating the cost value needs adding or production operation. But by omitting some offset value it's possible to reduce the time complexity.

IV. EXPARIMENTLA RESULTS

To comparing the performance, proposed method used in HEVC reference software HM11.0. There are 8 different test sequences are used to provide the results. Test condition OS is Windows 7 64bit, 32G RAM, and Microsoft visual studio 2008 C/C++ as a compiler. Quantization coefficients are 22, 27, 32 and 37.

In this experiment only use an All-intra mode. Because if use Low-delay mode or Random-access mode, then it is easy to get a more efficient results. LD and RA are use the inter image duplications are frequently appear. So those modes are more effective in data compression. But those two modes use a P frame and B frame, so it have to wait until reference frame processing was finished. In this paper target to decrease the complexity, so we use only All-intra mode.

As an experimental results, table 2 show the result when use the least used band restrict method. By using this method we can get 0.05% BD-rate is increase. In table 4. We can check by using this method about 8.15% time complexity decrease.

TABLE II. BD-RATE RESULTS OF BAND RESTIRC METHOD

Sequences	**BD-Rates (%)**
Traffic	0.00
PeopleOnStreet	0.04
Kimono	0.00
BQTerrace	0.00
BasketballDrill	0.00
BQMall	0.00
BQSquare	0.00
RaceHorses	0.43
Average	**0.05**

Secondly proposed method which changing the rate of offset value, as a result of this method we get 0.03% BD-rate increase. This result is shown in table3. And also by using this method we can reduce the time complexity about 6.07%.

Additional experimental condition is when use the proposed two method simultaneously. First proposed method is just restrict the band offset calculation procedure. And second proposed method control the change rate of offset value. If those two method is used in the same time, then each method compensate other method's weak point. So we can reduce time complexity more efficiently compare to when each method is solely used.

TABLE III. BD-RATE RESULTS OF OFFSET VALUE CHANGE METHOD

Sequences	BD-Rates (%)
Traffic	0.00
PeopleOnStreet	0.02
Kimono	0.00
BQTerrace	0.01
BasketballDrill	0.00
BQMall	0.00
BQSquare	0.00
RaceHorses	0.26
Average	**0.03**

V. CONCLUSION

In this paper, to prove the reduction of encoder time complexity performance use the 8 standard sequences. And investigate the band usage to restrict some specific band which the least used band. By using this method we can omit the procedure which calculate the cost value and comparing operations. Also to find the optimal offset value, the original SAO method use the offset value changing rate just 1. But adjusting this changing rate 1 to 3, we did not have to calculate the all of the offset value for each band. Lastly when use those proposed two method simultaneously, we can efficiently reduce the complexity compare to when each method is solely used.

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TABLE IV. PERFORMANCE OF PROPOSED METHOD

Class	Sequence	QP	Proposed Method1	Proposed Method1	Proposed Method1&2
A	Traffic	22	-2.36	-1.17	-2.20
		27			
		32			
		37			
	People OnStreet	22	-1.99	-0.83	-3.2
		27			
		32			
		37			
B	Kimono	22	-16.05	-8.96	-8.59
		27			
		32			
		37			
	BQ Terrace	22	-2.07	0.05	-4.66
		27			
		32			
		37			
C	Basket Ball Drill	22	-4.23	-10.05	-8.93
		27			
		32			
		37			
	BQ Mall	22	-9.23	-7.44	-7.33
		27			
		32			
		37			
D	BQ Square	22	-14.93	-16.25	-14.07
		27			
		32			
		37			
	Race Horeses	22	-14.4	-16.3	-19.53
		27			
		32			
		37			
Average			**-8.15**	**-6.07**	**-8.56**