Joint Collaborative Team on Video Coding (JCT-VC)
of ITU-T SG16 WP3 and ISO/IEC JTC1/SC29/WG11
6th Meeting: Torino, IT, 14-22 July, 2011

Document: JCTVC-F258

Title: **CE12: SK Telecom/SKKU Deblocking Filter**

Status: Input Document to JCT-VC

Purpose: Proposal

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Abstract

Based on previous contribution of JCTVC-E417 [1], this contribution proposes a deblocking filter modified from the one in HM 3.0. It is reported that the proposed filter has BDBR reduction of 1.2% (HE_IO), 1.1% (HE_RA), 1.6% (HE_LD) and 1.0% (LC_IO), 0.8% (LC_RA), 1.0% (LC_LD) with approximately similar decoding time compared to HM3.0 anchor.

1 Introduction

The HEVC deblocking filter in HM3.0 shows good objective and subjective quality with simpler computational complexity than the MPEG-4 Part.10 AVC/H.264 deblocking filter. To further improve its objective and subjective quality, in this contribution, some modifications from the HM3.0 deblocking filter are addressed as follows:

1. Boundary strength (bS) decision and clipping value (t_c) control (luma and chroma)
2. Filter type decision (luma only)
3. Weak filter (luma only)

2 Algorithm description

As described above, the proposed method has a few modifications from the HM3.0 deblocking filter – bS decision and clipping value control, filtering decision, filter type decision and modified weak filter. Except the above modifications, other deblocking filtering processes are the same as the HM3.0.

2.1 Luma bS decision and clipping value control

In current HM3.0 deblocking filter, two bS (3 and 4) values can be chosen when P or Q block is intra coded. If a boundary between P and Q is a CU boundary, its bS value is set to 4. Otherwise bS value is set

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to 3. According to our observation and previous contributions [2, 3, 4], blocking artifact for intra coded block is more affected by intra prediction modes. So, in this contribution, bS value is selected based on intra prediction modes of P and Q blocks.

Compared to the previous proposed contribution [1], the bS decision process for intra coded blocks is modified simpler in this contribution to avoid computational complexity with similar objective and subjective quality. In this contribution, the proposed bS decision process can assign two bS (3 and 4) values (as the same number as HM3.0 deblocking filter) for intra coded blocks. Its new bS decision process is as follows: the proposed method controls bS for intra coded blocks (bS=3, 4) as shown in Table 1. When P and Q blocks are inter coded blocks, bS value is selected as the same manner as in HM3.0 (bS=0, 1, 2).

Table 1. bS Decision for Luma

Conditions	bS	Compared to HM3.0
P and Q have *different* intra prediction modes*	4	Modified
P and Q have *the same* intra prediction mode*	3	Modified
P and Q are inter coded block, *and* P and/or Q has non-zero coded coefficients	2	No change
P and Q are inter coded block, *and* P and Q have no non-zero coded coefficients, *and* P and Q refer to the different reference pictures, *or* P and Q have MV values that differ by one sample or more	1	No change
Otherwise	0	No change

*If only one of P and Q is intra coded, then treat the case as having "different" intra prediction modes.

If P and/or Q are intra coded block and its intra prediction modes are different, bS is set to 4. For this case, two different cases can happen – only one of P and Q blocks is intra coded block and both P and Q are intra coded blocks as shown in Fig. 1.

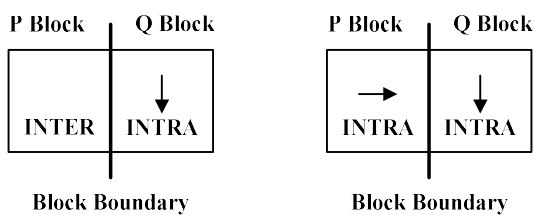

Fig. 1. Examples of bS=4 case

To handle these cases easily, if only one of P and Q is intra coded block, the proposed method regards that its intra prediction modes are different, therefore bS=4 is assigned. Otherwise, as shown in Fig. 2, when both P and Q are intra coded and its intra prediction modes are the same, bS is set to 3 to avoid an unintended smoothing over the intra coded block boundary between P and Q. When P and Q have the same intra prediction mode, the effects of prediction in P and Q are expected not quite different from each other and the boundary between the two blocks is likely to show relatively weaker blocking artifact.

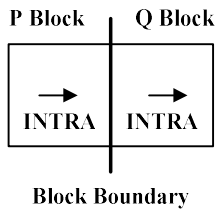

Fig. 2. Examples of bS=3 case

The deblocking filter in HM3.0 sets the clipping value (t_c) by referring to the LUT table (Table 8-13 in JCTVC-E603 [5]) using the index (QP + t_c offset) for intra coded block. In HM3.0, t_c offset is set to 4 when bS value is greater than 2. To assign a more suitable t_c value, we propose to define a modified t_c offset for intra coded blocks. By using the proposed t_c offset, unlikely to the previous proposal [1], this proposal needs no additional LUT table to control the clipping value (t_c) by bS. The t_c offset value is defined by bS value as follows:

t_c offset = 3 when bS = 4

t_c offset = 1 when bS = 3

t_c offset = 0 when bS = 1, 2

2.2 Chroma bS decision and clipping value control

In HM3.0, the chroma bS value is simply inherited from luma bS value without its independent bS decision process. However, some of chroma coding conditions of P and Q blocks (such as chroma intra prediction mode and non-zero coded chroma coefficient) can be different from luma ones. Therefore, in this contribution, an independent chroma bS decision process is performed in the same manner as the luma bS decision process as described in section 2.1. In the chroma bS decision process, bS=1 case needs not be checked. The same motion data (such as reference picture and motion vector) is shared for luma and chroma blocks. The t_c offset value for chroma filtering is also defined by the same manner as luma case.

2.3 Luma filtering decision

In the proposed method, filtering decision process is in the same way as the HM3.0 design. If the following inequality is satisfied, then filtering is performed. Note that this is a block-level decision.

	$p_{3,0}$	$p_{2,0}$	$p_{1,0}$	$p_{0,0}$	$q_{0,0}$	$q_{1,0}$	$q_{2,0}$	$q_{3,0}$	
	$p_{3,1}$	$p_{2,1}$	$p_{1,1}$	$p_{0,1}$	$q_{0,1}$	$q_{1,1}$	$q_{2,1}$	$q_{3,1}$	
	$p_{3,2}$	$\mathbf{p_{2,2}}$	$\mathbf{p_{1,2}}$	$\mathbf{p_{0,2}}$	$\mathbf{q_{0,2}}$	$\mathbf{q_{1,2}}$	$\mathbf{q_{2,2}}$	$q_{3,2}$	
Block	$p_{3,3}$	$p_{2,3}$	$p_{1,3}$	$p_{0,3}$	$q_{0,3}$	$q_{1,3}$	$q_{2,3}$	$q_{3,3}$	Block
P	$p_{3,4}$	$p_{2,4}$	$p_{1,4}$	$p_{0,4}$	$q_{0,4}$	$q_{1,4}$	$q_{2,4}$	$q_{3,4}$	Q
	$p_{3,5}$	$\mathbf{p_{2,5}}$	$\mathbf{p_{1,5}}$	$\mathbf{p_{0,5}}$	$\mathbf{q_{0,5}}$	$\mathbf{q_{1,5}}$	$\mathbf{q_{2,5}}$	$q_{3,5}$	
	$p_{3,6}$	$p_{2,6}$	$p_{1,6}$	$p_{0,6}$	$q_{0,6}$	$q_{1,6}$	$q_{2,6}$	$q_{3,6}$	
	$p_{3,7}$	$p_{2,7}$	$p_{1,7}$	$p_{0,7}$	$q_{0,7}$	$q_{1,7}$	$q_{2,7}$	$q_{3,7}$	

Block Boundary

Fig. 3. Samples for filtering decision

$$d = | p_{2,2} - 2*p_{1,2} + p_{0,2} | + | q_{2,2} - 2*q_{1,2} + q_{0,2} | + | p_{2,5} - 2*p_{1,5} + p_{0,5} | + | q_{2,5} - 2*q_{1,5} + q_{0,5} | < \beta$$

However, in this proposal, the value of d is calculated by a sum of d_{p0} and d_{q0} as follows:

$$d_{p0} = | p_{2,2} - 2*p_{1,2} + p_{0,2} | + | p_{2,5} - 2*p_{1,5} + p_{0,5} |$$

$$d_{q0} = | q_{2,2} - 2*q_{1,2} + q_{0,2} | + | q_{2,5} - 2*q_{1,5} + q_{0,5} |$$

The value of d_{p0} and d_{q0} are later used also for luma weak filtering process.

2.4 Chroma filtering decision

In HM3.0 deblocking filter, the first chroma pixels (p_0 and q_0) from the boundary are filtered only for bS > 2 (i.e., P and/or Q is intra coded block). No chroma filtering is done for inter coded block. However, in this proposal, the first chroma pixels (p_0 and q_0) are filtered for bS > 1. Other chroma filtering process is not changed.

2.5 Luma filter type decision

HM3.0 deblocking filter adopts two different types of deblocking filters – a strong and a weak filter. The strong filter is a strong 4-tap or 5-tap smoothing filter that refers to four samples from the boundary on both P and Q sides ($p_3 \sim p_0$ and $q_0 \sim q_3$). Therefore, the strong filter should be applied only to very flat and smooth image regions. In current HM3.0 deblocking filter for deciding the type of filters, following three inequality conditions are checked and a strong filter is applied when the thee inequalities are satisfied [5].

$$d < (\beta >> 2)$$

$$| p_3 - p_0 | + | q_0 - q_3 | < (\beta >> 2)$$

$$| p_3 - p_0 | < (5*t_c + 1) >> 1$$

However, these conditions are not sufficient. To have better selection of filter type, in this contribution, for strong filter, one inequality condition is added to the above three inequality conditions as follows:

	$p_{3,0}$	$p_{2,0}$	$p_{1,0}$	$p_{0,0}$	$q_{0,0}$	$q_{1,0}$	$q_{2,0}$	$q_{3,0}$	
	$p_{3,1}$	$p_{2,1}$	$p_{1,1}$	$p_{0,1}$	$q_{0,1}$	$q_{1,1}$	$q_{2,1}$	$q_{3,1}$	
	$\mathbf{p_{3,2}}$	$\mathbf{p_{2,2}}$	$\mathbf{p_{1,2}}$	$p_{0,2}$	$q_{0,2}$	$\mathbf{q_{1,2}}$	$\mathbf{q_{2,2}}$	$\mathbf{q_{3,2}}$	
Block	$p_{3,3}$	$p_{2,3}$	$p_{1,3}$	$p_{0,3}$	$q_{0,3}$	$q_{1,3}$	$q_{2,3}$	$q_{3,3}$	Block
P	$p_{3,4}$	$p_{2,4}$	$p_{1,4}$	$p_{0,4}$	$q_{0,4}$	$q_{1,4}$	$q_{2,4}$	$q_{3,4}$	Q
	$\mathbf{p_{3,5}}$	$\mathbf{p_{2,5}}$	$\mathbf{p_{1,5}}$	$p_{0,5}$	$q_{0,5}$	$\mathbf{q_{1,5}}$	$\mathbf{q_{2,5}}$	$\mathbf{q_{3,5}}$	
	$p_{3,6}$	$p_{2,6}$	$p_{1,6}$	$p_{0,6}$	$q_{0,6}$	$q_{1,6}$	$q_{2,6}$	$q_{3,6}$	
	$p_{3,7}$	$p_{2,7}$	$p_{1,7}$	$p_{0,7}$	$q_{0,7}$	$q_{1,7}$	$q_{2,7}$	$q_{3,7}$	

Block Boundary

Fig. 4. Samples for filter type selection

$$d_{p1} < \beta_s \quad \text{and} \quad d_{q1} < \beta_s$$

where $d_{p1} = | p_{3,2} - 2*p_{2,2} + p_{1,2} | + | p_{3,5} - 2*p_{2,5} + p_{1,5} |$, and $d_{q1} = | q_{3,2} - 2*q_{2,2} + q_{1,2} | + | q_{3,5} - 2*q_{2,5} + q_{1,5} |$

To avoid computational complexity increase, this condition is calculated for each 8x8 block as the same way as filtering decision process as shown in Fig. 4. That is, it is a block-level decision. In the proposed method, the strong filter is applied when above all four inequality conditions are satisfied.

2.6 Luma weak filter

In this proposal, a normal filter of MPEG-4 Part.10 AVC/H.264 is used for weak filtering as follows:

$$\triangle = \text{Clip3}\ (-t_c, t_c, ((q_0 - p_0) << 2) + (q_1 - p_1) + 4) >> 3))$$

The samples at the second position from the boundary (p_1 and q_1) are selectively modified by $\triangle/2$ value based on the individual conditions at P and Q sides as follows:

$$p_1' = \begin{cases} \text{Clip0-255}\ (p_1 + \Delta/2) & \textit{if} \quad d_{p0} < \beta_s \\ p_1 & \textit{else} \end{cases}$$

$$q_1' = \begin{cases} \text{Clip0-255}\ (q_1 - \Delta/2) & \textit{if} \quad d_{q0} < \beta_s \\ q_1 & \textit{else} \end{cases}$$

When both conditions ($d_{p0} < \beta_s$ and $d_{q0} < \beta_s$) are not satisfied, the second samples from the boundary (p_1 and q_1) are not modified. Therefore, in this case, the samples at the first position from the boundary are modified by $\triangle/2$ value to minimize discontinuity between the first sample and the second sample from the boundary. Therefore, the first samples from the boundary (p_0 and q_0) are modified as follows:

$$p_0' = \begin{cases} \text{Clip0-255}\ (p_0 + \Delta/2) & \textit{if} \quad d_{p0} < \beta_s \ \textit{and} \ d_{q0} < \beta_s \\ \text{Clip0-255}\ (p_0 + \Delta) & \textit{else} \end{cases}$$

$$q_0' = \begin{cases} \text{Clip0-255}\ (q_0 - \Delta/2) & \textit{if} \quad d_{p0} < \beta_s \ \textit{and} \ d_{q0} < \beta_s \\ \text{Clip0-255}\ (q_0 - \Delta) & \textit{else} \end{cases}$$

3 Experimental results

The proposed method is implemented on HM3.0 software and simulated under CE12 conditions [6]. Table 2 shows the summarized coding performance of the proposed method compared to HM3.0 anchor. More detailed results are included in *JCTVC-F258.xls*.

Table 2. Experimental results of the proposed deblocking filter compared to the HM3.0 anchor

	Intra Only HE			Intra Only LC		
	Y	U	V	Y	U	V
Class A	-1.7	-0.5	-0.5	-1.1	-0.6	-0.5
Class B	-1.3	-0.5	-0.5	-1.1	-0.7	-0.6
Class C	-1.0	-0.8	-0.7	-1.0	-0.9	-0.8
Class D	-0.9	-0.7	-0.7	-0.9	-0.7	-0.7
Class E	-1.3	0.0	-0.1	-1.0	0.0	-0.1
Overall	**-1.2**	**-0.5**	**-0.5**	**-1.0**	**-0.6**	**-0.6**
Enc Time[%]	102%			100%		
Dec Time[%]	100%			101%		

	Random Access HE			Random Access LC		
	Y	U	V	Y	U	V
Class A	-1.5	-0.4	-0.1	-0.9	0.2	0.6
Class B	-1.3	-0.8	-0.8	-1.0	-0.7	-0.5
Class C	-1.0	-0.6	-0.7	-0.8	-0.4	-0.6
Class D	-0.8	-0.8	-0.8	-0.7	-0.4	-0.4
Class E						
Overall	**-1.1**	**-0.7**	**-0.6**	**-0.8**	**-0.3**	**-0.3**
Enc Time[%]	109%			100%		
Dec Time[%]	99%			100%		

	Low delay B HE			Low delay B LC		
	Y	U	V	Y	U	V
Class A						
Class B	-1.6	-1.2	-1.4	-1.0	-1.1	-0.7
Class C	-1.1	-0.6	-0.8	-0.8	0.4	-0.2
Class D	-1.0	-0.3	-0.3	-0.7	-0.1	-0.2
Class E	-3.0	-2.7	-2.8	-1.6	-4.7	-3.8
Overall	**-1.6**	**-1.1**	**-1.2**	**-1.0**	**-1.1**	**-1.1**
Enc Time[%]	96%			100%		
Dec Time[%]	99%			100%		

4 Concluding remarks

This contribution proposed a deblocking filter modified from the one in the HM3.0. According to the test condition agreed by CE12, it is reported that the proposed filter has BDBR gain of 1.2% (HE_IO), 1.1% (HE_RA), 1.6% (HE_LD) and 1.0% (LC_IO), 0.8% (LC_RA), 1.0% (LC_LD) with approximately similar decoding time compared to HM 3.0. The proposal shows advantage in BDBR gains with only a few modifications from the current HM3.0. Therefore, the proposed method is easy to combine with other deblocking filtering methods. It is recommended to employ this simple mechanism in coming HM design.

5 References

[1] J. Yang, K. Won, B. Jeon and J. Lim, "CE12 Subset1: SKT/SKKU Deblocking Filter," JCTVC-E417, Geneva, March 2011.

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6 Patent rights declaration(s)

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