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| *Title:* | **CE12 Subset1: SKT/SKKU Deblocking Filter** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Proposal | | |
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# Abstract

This contribution proposes a deblocking filter modified from the one in the HM 2.0 with special attention to intra coded blocks. It is reported that the proposed filter has BDBR reduction of 1.2% (HE\_IO), 1.4% (HE\_LD), 1.0% (HE\_RA) and 1.1% (LC\_IO), 1.0% (LC\_LD), 0.9% (LC\_RA) with approximately similar encoding and decoding time compared to HM 2.0.

# Introduction

In the HM 2.0 deblocking filter, boundary strength (bS) is selected depending on the coding conditions of adjacent blocks (P and Q). However, the bS decision process does not pay full attention to various coding conditions of intra coded blocks. Moreover, the selected bS is not utilized to finely control the strength of deblocking filter (e.g., tc value is only changed according to intra/inter mode of P and Q). Therefore, this contribution proposes a few modifications to the HM 2.0 deblocking filter as following:

* HM 2.0 assigns bS value of either 3 or 4 to intra blocks. It is proposed to assign bS value of 0 ~ 4 to intra blocks to pay closer attention to various coding conditions of intra coded blocks. The bS decision depends on relative direction of intra prediction and deblocking block boundary.
* HM 2.0 sets the parameter tc referring to the LUT table (Table in 8-13 in JCTVC-D503) using the index QP+4 for intra block. This proposal defines a modified LUT for intra blocks. It has tc values defined for different bS values of 1,2,3,4. The modified LUT intends to have finer tc values reflecting various bS values for intra blocks. Note that HM 2.0 assigns bS value 3 for intra block not at CU boundary, and at CU boundary, bS is increased by 1, thus 4 is assigned. Following, same tc value is used for bS=3 and 4.
* This proposal also modifies filtering decision for the second position pixels from block boundary, and defines a modified weak filter.

# Algorithm description

The proposed method has a few modifications from the current HM 2.0 deblocking filter – bS decision and tc value setting for intra coded blocks, modified filtering decision for the second position pixels from block boundary, and modified weak filter. Except above modifications, other deblocking filtering processes are the same as the HM 2.0 .

## bS decision for intra blocks

In this proposal, the bS decision process for intra blocks is slightly modified from the previous proposed contribution [1]. Its new bS decision process is as follows: when P and Q blocks are inter-coded blocks, bS value is selected as the same manner as the HM 2.0. Otherwise, the proposed method controls bS for intra-coded blocks as shown in Table 1.

Table 1. bS decision for intra coded blocks

|  |  |
| --- | --- |
| Conditions | bS |
| Q is intra coded,  *and* Q is predicted in the same direction as the deblocking filtering,  *and* Q has no coded residual coefficient. | 0 |
| P and Q are intra coded,  *and* P and Q have the same intra prediction direction,  *and* boundary direction & prediction direction are the same. | 1 |
| P and Q are intra coded,  *and* P and Q have the same intra prediction direction,  *and* boundary direction & prediction direction are different. | 2 |
| P and Q are intra coded,  *and* P and Q have DC intra prediction modes. | 3 |
| Otherwise | 4 |

As the first step, the first set of conditions in Table 1 is checked to see whether bS can be set 0 or not. When Q is intra coded block and predicted in the same direction as the deblocking filtering, blocking artifact caused *by prediction* does not occur on the block boundary. However, there is still possibility of having blocking artifacts *by quantization*. Therefore, in the case as shown in Fig 1, additional condition should be checked: if Q has no coded residual coefficient, bS value is set to 0.This makes sense since, in this case, blocking artifact caused by quantization does not exist either. The decision has computational benefit as well since bS value of 0 can avoid unnecessary deblocking filter process.



Fig 1. Example of bS=0 case

Following, the second set of cases in Table 1 is checked. If P and Q have the same intra prediction mode, and its prediction direction is identical to boundary direction as in Fig. 2(a), bS is set to 1 to avoid an unintended smoothing over the block boundary between P and Q. On the other hand, if intra prediction is performed across the given block boundary, bS is set to 2. Since deblocking filtering is applied to vertical and horizontal block boundaries, vertical and horizontal intra prediction modes are considered to check for above two cases.

(a) Same direction (b) Different direction

Fig 2. Example of block boundary direction and prediction direction

Lastly, if both of P and Q have DC mode, it means that P and Q are included in flat regions. Thus, in this case, relatively strong filtering can be helpful, so bS is set to 3. Otherwise, that is, when P and Q has different prediction type or different prediction direction, the effects of prediction and quantization in P and Q are quite different each other and the boundary between P and Q is likely to show the strongest blocking artifact. For this case, the strongest deblocking filter (bS=4) is applied. According to QP and the selected bS, the strength of deblocking filter (tc) is changed.

## Filtering decision

In the proposed method, the pixels (p0 and q0) which are at the first position from the boundary are always filtered when the filtering decision conditions are satisfied. This is in the same way as the HM 2.0 design as follows:

d = | p2,2 – 2\*p1,2 + p0,2 | + | q2,2 – 2\*q1,2 + q0,2 | + | p2,5 – 2\*p1,5 + p0,5 | + | q2,5 – 2\*q1,5 + q0,5 | < β

However, for the pixels at the second positions from the boundary (that is, p1 and q1), two additional conditions are checked to decide whether to apply the deblocking filtering or not. Each of two conditions is satisfied, p1 and q1 are filtered, respectively.

dp = | p2,2 – 2\*p1,2 + p0,2 | + | p2,5 – 2\*p1,5 + p0,5 | < βp

dq = | q2,2 – 2\*q1,2 + q0,2 | + | q2,5 – 2\*q1,5 + q0,5 | < βq

## Luma weak filter

HM 2.0 adopts two different types of deblocking filters – a strong and a weak filter. In this proposal, the weak filter in HM 2.0 is modified as follows:

△ = Clip3 (-tc, tc, ((q0 – p0) << 2) + (q1 – p1) + 4) >> 3))

p0' = Clip0-255 (p0 + △)

q0' = Clip0-255 (q0 – △)

p1' = Clip0-255 (p1 + △/2) when dp < βp

q1' = Clip0-255 (q1 – △/2) when dq < βq

The first pixels from the boundary (p0 and q0) are modified by the same deblocking filter of H.264/AVC. To reduce complexity, However, the pixels at the second position from the boundary (p1 and q1) are selectively modified by △/2 value based on the inequlity respectively of (dp < βp) and (dq < βq)

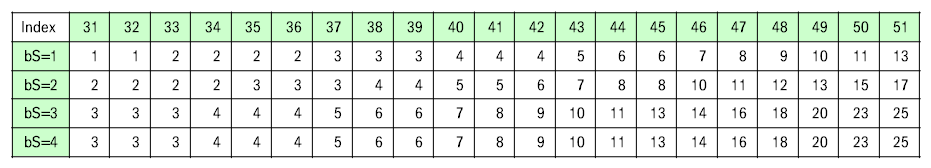
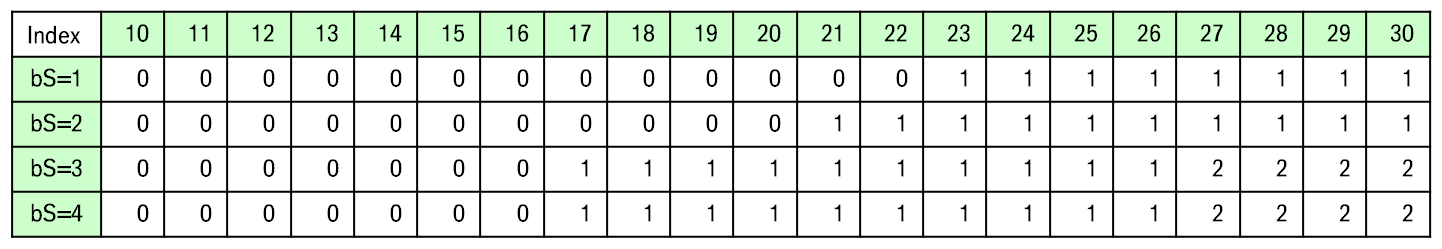
## Chroma filtering

In HM2.0, the first chroma pixels (p0 and q0) from the boundary are filtered only for bS > 2 (i.e., P or Q is intra coded block). No chroma filtering is done for inter coded block. In the same spirit, in this proposal, the chroma pixels (p0 and q0) are filtered only for intra coded block (with bS = 1, 2, 3, 4). In case of inter block, no chroma filtering is performed. Therefore, the chroma filtering is essentially the same as HM 2.0.

## Modified tc setting for Intra blocks

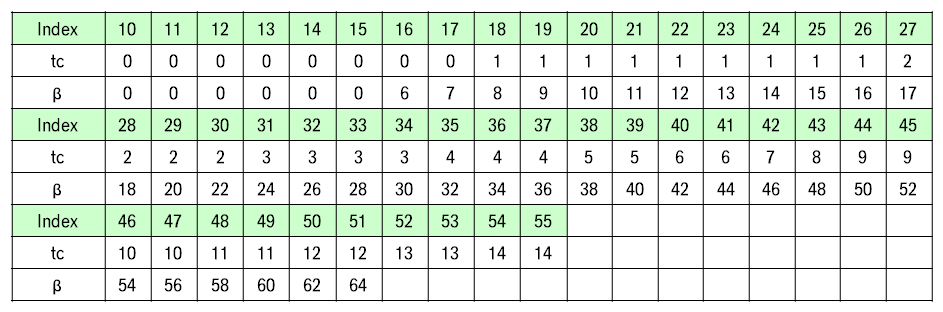
HM 2.0 sets the parameter tc referring to the LUT table (Table in 8-13 in JCTVC-D503) using the index QP+4 for intra block. This proposal defines a modified LUT for intra blocks. It has tc values defined each for different bS values of 1,2,3,4. Therefore, the modified LUT tries to have finer tc values better reflecting various bS values for intra blocks. Note that HM 2.0 assigns bS value 3 for intra block not at CU boundary. At CU boundary, bS is increased by 1, thus 4 is assigned. In Table 1, tc is assumed zero for Index < 10.

Table 1. Modified tc setting for intra blocks



For tc setting for inter blocks and  values, the same LUT in Table 2 is used as in HM 2.0.

Table 2. tc and  setting for inter blocks (same as HM 2.0)



# Experimental results

The proposed method is implemented on HM 2.0 software and simulated under CE12 Subset1 conditions [4]. Table 3 shows the summarized coding performance of the proposed method compared to HM2.0 anchor. More detailed results are included in *JCTVC-E417\_SKKU\_DF\_result.xls*.

Table 3. Test Result according to CE12 Condition

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -1.6 | -0.6 | -0.6 | -1.5 | -0.6 | -0.7 |
| Class B | -1.2 | -0.8 | -0.7 | -1.1 | -0.7 | -0.6 |
| Class C | -0.9 | -0.8 | -0.8 | -0.9 | -0.7 | -0.6 |
| Class D | -0.8 | -0.7 | -0.8 | -0.8 | -0.6 | -0.5 |
| Class E | -1.3 | 0.0 | -0.1 | -1.0 | 0.3 | 0.3 |
| All | -1.2 | -0.6 | -0.6 | -1.1 | -0.5 | -0.4 |
| Enc Time[%] | 99% | | | 100% | | |
| Dec Time[%] | 101% | | | 101% | | |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Random access | | | Random access LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -1.3 | -0.3 | -0.6 | -1.1 | -0.7 | -0.6 |
| Class B | -1.1 | -0.7 | -0.6 | -0.9 | -0.7 | -0.6 |
| Class C | -0.9 | -0.7 | -0.7 | -0.8 | -0.7 | -0.8 |
| Class D | -0.6 | -0.8 | -0.6 | -0.6 | -0.8 | -0.6 |
| Class E |  |  |  |  |  |  |
| All | -1.0 | -0.6 | -0.6 | -0.9 | -0.7 | -0.6 |
| Enc Time[%] | 105% | | | 110% | | |
| Dec Time[%] | 100% | | | 101% | | |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Low delay | | | Low delay LoCo | | |
|  | Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A |  |  |  |  |  |  |
| Class B | -1.4 | -0.2 | -0.4 | -1.0 | -0.5 | -0.2 |
| Class C | -1.0 | 0.0 | -0.2 | -0.7 | -0.4 | -0.3 |
| Class D | -0.9 | -0.5 | -0.4 | -0.5 | -0.1 | -0.1 |
| Class E | -2.9 | -0.9 | -0.1 | -1.9 | -0.3 | 0.2 |
| All | -1.4 | -0.4 | -0.3 | -1.0 | -0.3 | -0.1 |
| Enc Time[%] | 103% | | | 106% | | |
| Dec Time[%] | 99% | | | 99% | | |

# Concluding remarks

This contribution proposed a deblocking filter modified from the one in the HM 2.0 with special attention to intra coded blocks. According to the test condition agreed by CE12, it is reported that the proposed filter has BDBR gain of 1.2% (HE\_IO) and 1.1% (LC\_IO) against HM 2.0. The subjective quality of the proposed method is also reported to be similar to that of the HM 2.0 anchor. The main contribution of this proposal is showing advantage of BDBR gains by having finer assignment of bS values for intra blocks. This simple extension of bS decision for intra blocks is relatively orthogonal to subsequent filters. 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.

# References

[1] J. Yang, K. Won, H. Yang, B. Jeon and J. Lim, “CE8 Subset1: Results of intra deblocking filter testing by SKKU/SKT (JCTVC-C130),” JCTVC-D334, Daegu, Jan. 2011.

[2] J. Yang, K. Won, B. Jeon, J. Lim and J. Song, “In-loop deblocking filtering for intra blocks,” JCTVC-C130, Oct, 2010.

[3] J. Yang, K. Won, H. Yang, B. Jeon, J. Lim, J. Song “In-loop deblocking filtering for intra blocks,” JCTVC-B075, July, 2010.

[4] A. Norkin, B. Jeon, M. Narroschke et al., “Description of CE12: Deblocking Filtering,” JCTVC-D612, Daegu, Jan. 2011.

# Patent rights declaration(s)

**SK Telecom and Sungkyunkwan University may have current or pending patent rights relating to the technology described in this contribution and, conditioned on reciprocity, is prepared to grant licenses under reasonable and non-discriminatory terms as necessary for implementation of the resulting ITU-T Recommendation | ISO/IEC International Standard (per box 2 of the ITU-T/ITU-R/ISO/IEC patent statement and licensing declaration form).**

Appendix

The experiment result in Table 4 (this is what was reported in JCTVC-E417) is a test result of the proposed method with following difference from the method for Table 3.

* Same tc value setting for intra (bS=1, 2) and inter (bS=1, 2) using the Table 1.
* Execute chroma filtering also for inter blocks (bS=1, 2)

Table 4. Test Result according to CE12 Condition

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | HE\_IO | | | LC\_IO | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -1.6 | -0.4 | -0.5 | -1.5 | -0.5 | -0.5 |
| Class B | -1.2 | -0.6 | -0.5 | -1.1 | -0.5 | -0.4 |
| Class C | -0.9 | -0.7 | -0.6 | -0.9 | -0.6 | -0.5 |
| Class D | -0.8 | -0.6 | -0.7 | -0.8 | -0.5 | -0.5 |
| Class E | -1.3 | 0.0 | -0.1 | -1.0 | 0.2 | 0.1 |
| All | -1.2 | -0.5 | -0.5 | -1.1 | -0.4 | -0.4 |
| Enc Time[%] | 101% | | | 100% | | |
| Dec Time[%] | 100% | | | 101% | | |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | HE\_RA | | | LC\_RA | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -1.1 | 2.6 | 2.8 | -0.6 | 5.3 | 5.7 |
| Class B | -1.0 | 1.3 | 1.1 | -0.6 | 1.3 | 1.3 |
| Class C | -0.7 | 0.9 | 0.7 | -0.5 | 1.2 | 0.8 |
| Class D | -0.6 | 1.1 | 1.1 | -0.4 | 1.4 | 1.5 |
| Class E |  |  |  |  |  |  |
| All | -0.9 | 1.5 | 1.4 | -0.5 | 2.2 | 2.2 |
| Enc Time[%] | 106% | | | 101% | | |
| Dec Time[%] | 100% | | | 101% | | |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | HE\_LD | | | LC\_LD | | |
|  | Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A |  |  |  |  |  |  |
| Class B | -1.2 | 1.2 | 0.9 | -0.5 | 1.6 | 2.3 |
| Class C | -0.8 | 1.6 | 1.9 | -0.2 | 2.7 | 2.1 |
| Class D | -0.8 | 2.6 | 3.2 | -0.2 | 3.9 | 4.6 |
| Class E | -2.7 | -3.4 | -2.7 | -1.9 | -6.4 | -3.7 |
| All | -1.3 | 0.8 | 1.0 | -0.6 | 0.9 | 1.7 |
| Enc Time[%] | 103% | | | 100% | | |
| Dec Time[%] | 98% | | | 101% | | |