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Question: Q6/SG16

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Title: Reduced Complexity Loop Filter

Purpose: Proposal

1 Introduction

During Portland meeting it has been pointed out that the TML-5 loop filter [1] is relatively complex in terms of performed number of operations. The current document describes a proposal for a significantly simplified loop filter which on average is 60-65% less complex than TML-5 loop filter and whose subjective and objective performance is similar to that of the current TML-5 loop filter.

2 Description of proposed loop filter

In the following description it is assumed that a vertical 4x4 grid boundary is to be filtered (that is, horizontal filtering takes place). Horizontal grid boundaries are filtered utilizing the same algorithm, but 'left' pixels should be substituted for 'above' pixels and 'right' pixels for 'below' pixels. Let us denote the set of eight pixels across a 4x4 block boundary as $l_4, l_3, l_2, l_1, r_1, r_2, r_3, r_4$.

Up to two pixels can be updated as a result of the filtering process on both sides of the boundary (that is at most l_2, l_1, r_1, r_2). The number of updated pixels on both sides of the boundary depends on corresponding right and left activity parameters a_r and a_l . Both activity parameters are limited by the so called overall activity parameter n :

$$n = \begin{cases} 0 & \Delta \geq \alpha \\ 1 & \alpha + \alpha/2 \leq 2\Delta < 2\alpha \\ 2 & \alpha \leq 2\Delta < \alpha + \alpha/2 \\ 3 & 2\Delta < \alpha \end{cases}$$

where $\Delta = |r_1 - l_1|$ is a positive integer representing gray level difference across the boundary, and α is a QP dependent threshold specified in Table 1.

QP	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
α	0	0	0	0	0	0	0	0	3	3	3	7	7	7	12	17	17	22	28	34	40	47	60	67	82	89	112	137	153	187	213	249
β	0	0	0	0	0	0	0	0	3	3	3	4	4	4	6	6	6	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14

Table 1. QP dependent threshold parameters α and β .

The right filter activity parameter a_r is equal to the smallest integer $i > 0$ not larger than n for which the inequality $|r_1 - r_{i+1}| * i > \beta$ holds. The QP dependent threshold β is given in Table 1. If no $i < n$ satisfies the condition, a_r is set to n . The left filter activity parameter a_l is obtained using the same set of rules substituting pixels on the right of the boundary r_i with pixels l_i on the left of the boundary. Once a_r and a_l are calculated, the pixels to be updated and their filtering support windows are determined by using Table 2. The same table applies for both right and left pixel although only right pixels are listed in the table. Information on how to filter the left pixels is obtained by swapping a_r and a_l and substituting r_1, r_2 with l_1, l_2 .

a_r (only if $a_l > 1$)	pixel r_1	pixel r_2
1	no filtering	no filtering
2	3 point avg	no filtering
3	3 point avg	3 point avg ⁽¹⁾

Table 2. Pixels to be updated and their support window dependency on a_r .
The mark ⁽¹⁾ indicates that filtered value of r_1 is used.

When filtering within P frames, the left (right) activity parameter is upper bounded by 2 if *strength* of the left (right) 4x4 block is no larger than 1. A strength value of 0, 1, 2, or 3 is assigned to each 4x4 block in the frame in exactly the same way as described in current TML-5 [1]. Finally, when either of pixels r_1, l_1 are updated by filtering then the difference is clipped in range $[-C, C]$ where $C = (\text{Clip}(\text{QP}, \text{strength}_{\text{left}}) + \text{Clip}(\text{QP}, \text{strength}_{\text{right}}) + a_r + a_l) / 2$. When pixel r_2 is updated by filtering then the difference is clipped to the range $[-C_{\text{right}}, C_{\text{right}}]$ with $C_{\text{right}} = \text{Clip}(\text{QP}, \text{strength}_{\text{right}})$. Similarly for pixel l_2 . The table $\text{Clip}(\text{QP}, \text{strength})$ is the same as the one listed in current TML-5 [1].

As pointed out in [2] certain disturbing 16x16 blocking artefacts occurred in smooth background sequences when TML-4 filtering was applied. As a result a longer tap filtering solution was proposed and adopted in TML-5 to alleviate the artefacts in question. Similarly, such safeguard is also incorporated into this proposal but a different test condition is performed. The longer tap filtering (5 point avg) is triggered along macroblock boundaries only when both a_r and a_l are equal to 3, Δ is in range $[2, \text{QP}/4 - 1]$ and at least another of the blocks is intra coded. Three samples for luminance and two samples for chrominance on both sides of the block boundary are filtered in these cases.

The proposed loop filter is applied on a 4x4 grid for both luminance and chrominance, first for all the vertical then for all the horizontal block boundaries. Similar to the current loop filter used in TML-5 the boundary is filtered only when the strengths of both 4x4 blocks are at least 1. RD-curves with average PSNR and complexity figures are shown in [VCEG-L25.xls](#). Subjective evaluations will be provided during upcoming Eibsee meeting.

- [1] Gisle Bjontegaard, "H.26L Test Model Long Term Number 5 (TML-5) draft0", document Q15-K-59, ITU-T Video Coding Experts Group (Question 15) Meeting, Oregon, USA 22-25 August, 2000.
- [2] Jani Lainema, Marta Karczewicz, "Concerns about TML-4 Intra coding", document Q15-K-35, ITU-T Video Coding Experts Group (Question 15) Meeting, Portland, Oregon, USA 22-25 August, 2000.