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PROVISIONAL APPLICATION FOR PATENT COVER SHEET – Page 1 of 2

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INVENTOR(S)		
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Additional inventors are being named on the _____ separately numbered sheets attached hereto

TITLE OF THE INVENTION (500 characters max):

Asymmetric deblocking decisions

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

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ENCLOSED APPLICATION PARTS (check all that apply)

☐ Application Data Sheet. See 37 CFR 1.76

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Docket Number: P33966-US1

Asymmetric deblocking decisions

1 Background

1.1 Technical Background/Existing Technology

Deblocking filters are used in the video coding standards in order to combat blocking artifacts. The blocking artifacts arise because the original video is split into blocks which are processed relatively independently. The blocking artifacts can arise due to different intra prediction of the block, quantization effects and motion compensation. Two particular variants of deblocking are described below.

These descriptions assume a vertical block boundary. The process is also done in the same way for horizontal block boundaries.

1.1.1 H.264 deblocking

In state of the art video coding such as H.264 there is an adaptive de-blocking filter/loop filter after prediction and residual reconstruction, but before storage of the reconstruction for later reference when encoding or decoding the subsequent frames. The deblocking filtering consists of several steps such as filter decisions, filtering operations, a clipping function and changes of pixel values. The decision to filter the border or not is made based on evaluating several conditions. Filter decisions depends on macro block (MB) type, MV difference between neighboring blocks, whether neighboring blocks has coded residuals and on the local structure of the current and/or neighboring blocks.

Then the amount of filtering for a pixel depends on the position of that pixel relative to the block border and on the quantization parameter value (QP value) used for residual coding.

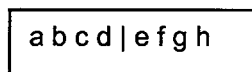


Figure 1 Pixel values across a vertical block boundary

The filter decision is based on comparing three pixel differences with three thresholds. The thresholds are adapted to the quantization parameter (QP).

If the following conditions are fulfilled the filter decision is positive, e.g. $\text{abs}(d-e) < \text{thr1}$, $\text{abs}(c-d) < \text{thr2}$, and $\text{abs}(e-f) < \text{thr2}$, where thr1 and thr2 are adapted based on QP.

There are two filtering modes in H.264. In the first filtering mode (normal filtering), filtering can be described with a delta value that the filtering change the current value with. The filtering for the pixel closest to the block boundary is

$$d' = d + \text{delta} \text{ and } e' = e - \text{delta}$$

where delta has been clipped off to a threshold $\pm \text{thr3}$ to a value that is constrained by the QP. More filtering is allowed for high QP than for low QP.

Clipping can be described as:

$$\text{delta_clipped} = \max(-\text{thr3}, \min(\text{thr3}, \text{delta}))$$

where thr3 is controlling the filter strength. A larger values of thr3 means that the filtering is stronger which means that a stronger low-pass filtering effect will happen.

The filter strength can be increased if any of the following two conditions also holds, e.g. $\text{abs}(b-d) < \text{thr2}$ and $\text{abs}(e-g) < \text{thr2}$. The filter strength is adapted by clipping the delta less, e.g. allow for more variation.

The second (strong) filtering mode is applied for intra macroblock boundaries only, when the following condition is fulfilled: $\text{abs}(d-e) < \text{thr1/4}$.

1.1.2 Deblocking in HEVC draft

$p_3 \ p_2 \ p_1 \ p_0 \mid q_0 \ q_1 \ q_2 \ q_3$
--

Figure 2 Pixel values across a vertical block boundary

In the draft HEVC specification, the deblocking filter works differently from H.264. The filtering is performed if at least one of the blocks on the side of the border is intra, or has non-zero coefficients, or the difference between the motion vector components of the blocks is greater or equal to one integer pixel. For example, if one is filtering the border between the blocks A and B from Figure 3, then the following condition should also be satisfied:

$$d = |p_2 - 2 \cdot p_1 + p_0| + |q_2 - 2 \cdot q_1 + q_0| + |p_5 - 2 \cdot p_4 + p_3| + |q_5 - 2 \cdot q_4 + q_3| < \beta$$

where β depends on QP. In the draft HEVC specification, there is a table for this where β increases with QP.

If the conditions are fulfilled and filtering is done between blocks A and B, one of two types of filtering (weak or strong filtering) is performed. The choice between the strong and the weak filtering is done separately for each line depending on the following conditions. For each line $i = 0, 7$, the strong filtering is performed if all the following conditions are true, otherwise, weak filtering is performed.

- $d < (\beta > 2)$
- **and** $(|p_3 - p_0| + |q_0 - q_3|) < (\beta > 3)$

$$\text{and } |p0_i - q0_i| < ((5 * t_c + 1) >> 1),$$

where t_c and β depends on qp. Their relations are shown in the table below.
The t_c is calculated as $t_c(qp+4)$ when A or B has PredMode==MODE_INTRA.

	p3 ₀	p2 ₀	p1 ₀	p0 ₀		q0 ₀	q1 ₀	q2 ₀	q3 ₀	
	p3 ₁	p2 ₁	p1 ₁	p0 ₁		q0 ₁	q1 ₁	q2 ₁	q3 ₁	
	p3 ₂	p2 ₂	p1 ₂	p0 ₂		q0 ₂	q1 ₂	q2 ₂	q3 ₂	
A	p3 ₃	p2 ₃	p1 ₃	p0 ₃		q0 ₃	q1 ₃	q2 ₃	q3 ₃	B
	p3 ₄	p2 ₄	p1 ₄	p0 ₄		q0 ₄	q1 ₄	q2 ₄	q3 ₄	
	p3 ₅	p2 ₅	p1 ₅	p0 ₅		q0 ₅	q1 ₅	q2 ₅	q3 ₅	
	p3 ₆	p2 ₆	p1 ₆	p0 ₆		q0 ₆	q1 ₆	q2 ₆	q3 ₆	
	p3 ₇	p2 ₇	p1 ₇	p0 ₇		q0 ₇	q1 ₇	q2 ₇	q3 ₇	

Figure 3 Notation of an 8 pixel part of a vertical edge for deblocking

The two filtering modes (weak and strong filtering) in the HEVC draft **Error! Reference source not found.** look like this:

Weak filtering

Weak filtering mode filtering is performed based on the above conditions. The actual filtering works by computing an offset (Δ), adding it to the original pixel value and clip the sum to a filtered output pixel value in the range of 0-255:

$$\begin{aligned} \Delta &= \text{Clip}(-t_c, t_c, (13 * (q0_i - p0_i) + 4 * (q1_i - p1_i) - 5 * (q2_i - p2_i) + 16) >> 5)) & i = 0, 7 \\ p0_i &= \text{Clip}_{0-255}(p0_i + \Delta) & i = 0, 7 \\ q0_i &= \text{Clip}_{0-255}(q0_i - \Delta) & i = 0, 7 \\ p1_i &= \text{Clip}_{0-255}(p1_i + \Delta/2) & i = 0, 7 \\ q1_i &= \text{Clip}_{0-255}(q1_i - \Delta/2) & i = 0, 7 \end{aligned}$$

where Clip is defined as

$$x' = \text{Clip}(A, B, x) \quad x' = x \text{ or if } x < A \quad x' = A \text{ or if } x > B \quad x' = B$$

and

$\text{Clip}_{0-255}(x)$ is defined as $\text{Clip}(0, 255, x)$

Strong filtering

Strong filtering mode is performed by the following set of operations.

$$\begin{aligned} p0_0 &= \text{Clip}_{0-255}((p2_1 + 2 * p1_1 + 2 * p0_1 + 2 * q0_1 + q1_1 + 4) >> 3); & i = 0, 7 \\ q0_0 &= \text{Clip}_{0-255}((p1_1 + 2 * p0_1 + 2 * q0_1 + 2 * q1_1 + q2_1 + 4) >> 3); & i = 0, 7 \\ p1_0 &= \text{Clip}_{0-255}((p2_1 + p1_1 + p0_1 + q0_1 + 2) >> 2); & i = 0, 7 \\ q1_0 &= \text{Clip}_{0-255}((p0_1 + q0_1 + q1_1 + q2_1 + 2) >> 2); & i = 0, 7 \\ p2_0 &= \text{Clip}_{0-255}((2 * p3_1 + 3 * p2_1 + p1_1 + p0_1 + q0_1 + 4) >> 3); & i = 0, 7 \\ q2_0 &= \text{Clip}_{0-255}((p0_1 + q0_1 + q1_1 + 3 * q2_1 + 2 * q3_1 + 4) >> 3); & i = 0, 7 \end{aligned}$$

1.2 Problems with Existing Solutions

Deblocking filtering in HEVC uses the same decision for both sides of the block border. It does not take into account that the structure on one side of the block border can be different and require different amount of filtering than the other side.

2 Basic Concept

In the current HEVC deblocking, the block boundary between the blocks A and B (Figure 3) is filtered, if the following condition is satisfied:

$$d = |p_{2_2} - 2 \cdot p_{1_2} + p_{0_2}| + |q_{2_2} - 2 \cdot q_{1_2} + q_{0_2}| + |p_{2_5} - 2 \cdot p_{1_5} + p_{0_5}| + |q_{2_5} - 2 \cdot q_{1_5} + q_{0_5}| < \beta$$

When calculating d , it is suggested to keep results at the intermediate steps, namely:

$$d_p = |p_{2_2} - 2 \cdot p_{1_2} + p_{0_2}| + |p_{2_5} - 2 \cdot p_{1_5} + p_{0_5}|$$

$$d_q = |q_{2_2} - 2 \cdot q_{1_2} + q_{0_2}| + |q_{2_5} - 2 \cdot q_{1_5} + q_{0_5}|$$

Then, these values can be used to decide how many pixels on the side of the block border that will be filtered. The values d_p and d_q are used in order to determine how many pixels to filter on each side of the block border. Lower values of d_p or d_q indicate that the structure on the respective side of the block border is more flat, therefore stronger filtering is allowed (or more pixels from the block border can be modified).

The deblocking filter is used in video coding. It functions in both the video encoder and in the video decoder. The video decoder can be implemented preferably in hardware but also in software. The same holds for the video encoder.

The algorithm description is given in the following:

1. Calculate d_p , calculate d_q ,
2. if ($d_p < thr1$)
3. {

Do normal filtering of block A (e.g. two pixels from the block border)
4. }
5. else {
6. do not filter the second pixel from the block border (or do not filter any pixels at all)
7. }

8. if ($d_q < thr2$)
9. {
 - Do normal filtering of block B (e.g. two pixels from the block border)
10. }
11. else {
12. do not filter the second pixel from the block border (or do not filter any pixels at all)
13. }
- 14.

The embodiment also decreases the computational complexity of the filter. And the embodiment could also be used to make filtering decision for each line separately. In this case, the following conditions are used for filtering decisions at each line i .

$$d_p = |p_{2i} - 2 \cdot p_{1i} + p_{0i}|$$

$$d_q = |q_{2i} - 2 \cdot q_{1i} + q_{0i}|$$

In this case, the algorithm given above shall be applied for each horizontal line of pixels crossing the vertical block boundary (see Fig. 3). The same applies for vertical lines of pixels crossing the horizontal block boundary.

3 Detailed description

3.1 Embodiment 1

The modified pixel values as the result of deblocking are calculated like in the following:

$$\begin{aligned} d_p &= |p_{22} - 2 \cdot p_{12} + p_{02}| + |p_{25} - 2 \cdot p_{15} + p_{05}| \\ d_q &= |q_{22} - 2 \cdot q_{12} + q_{02}| + |q_{25} - 2 \cdot q_{15} + q_{05}| \end{aligned}$$

$$\Delta = (9 \cdot (q_0 - p_0) - 3 \cdot (q_1 - p_1)) / 16$$

$$p_0' = p_0 + \Delta$$

$$q_0' = q_0 - \Delta$$

if ($d_p < thrP$)
{

$$\Delta_p = (p_0 + p_2 - 2 \cdot p_1 + 2 \cdot \Delta) / 4;$$

```

        p1' = p1 + Δp
    }
    if ( dq < thrQ )
    {

        Δq = (q0+q2-2*q1-2*Δ)/4;

        q1' = q1 + Δq

    }

```

The values of *thrP* and *thrQ* usually depend on QP. One solution is to use the same values of *thrP* and *thrQ* that are equal to the value of β with some multiplier. For example, the value $thrP = thrB = \beta/6$ can be used. The β is read from the table $\beta(QP)$.

As another variant of the embodiment, the threshold can be read from a separate tables *thrP*(QP), *thrQ*(QP).

3.2

Embodiment 2

Exact formulas for computation of embodiment 1 in the programming language can look like in the text below. Here, the Clip3 function is clipping of the output values to the range between the two first function arguments.

```

Int xCalcDP( Pel* piSrc, Int iOffset)
{
    return abs( piSrc[-iOffset*3] - 2*piSrc[-iOffset*2] + piSrc[-iOffset] );
}

Int xCalcDQ( Pel* piSrc, Int iOffset)
{
    return abs( piSrc[0] - 2*piSrc[iOffset] + piSrc[iOffset*2] );
}

Int iDP = xCalcDP( piTmpSrc+iSrcStep*(iIdx*uiPelsInPart+iBlkIdx*DEBLOCK_SMALLEST_BLOCK+2),
iOffset) + xCalcDP( piTmpSrc+iSrcStep*(iIdx*uiPelsInPart+iBlkIdx*DEBLOCK_SMALLEST_BLOCK+5),
iOffset);
Int iDQ = xCalcDQ( piTmpSrc+iSrcStep*(iIdx*uiPelsInPart+iBlkIdx*DEBLOCK_SMALLEST_BLOCK+2),
iOffset) + xCalcDQ( piTmpSrc+iSrcStep*(iIdx*uiPelsInPart+iBlkIdx*DEBLOCK_SMALLEST_BLOCK+5),
iOffset);

Int iSideThreshold = iBeta/6;

Bool bFilterP = (iDP < iSideThreshold);
Bool bFilterQ = (iDQ < iSideThreshold);

delta = (9*(m4-m3) -3*(m5-m2) + 8)>>4 ;

if ( abs(delta) < iThrCut )
{
    Int tc2 = tc>>1;

    delta = Clip3(-tc, tc, delta);
    piSrc[-iOffset] = Clip((m3+delta));
    piSrc[0] = Clip((m4-delta));
}

```

```

if(bFilterP)
{
    Int delta1 = Clip3(-tc2, tc2, (( (m1+m3+1)>>1) - m2+delta)>>1));
    piSrc[-iOffset*2] = Clip((m2+delta1));
}
if(bFilterQ)
{
    Int delta2 = Clip3(-tc2, tc2, (( (m6+m4+1)>>1) - m5-delta)>>1));
    piSrc[ iOffset] = Clip((m5+delta2));
}

```

3.3 Embodiment 3

This part describes how the embodiment is applied separately for each line crossing the block boundary.

$$d_{pi} = |p2_i - 2*p1_i + p0_i|$$

$$d_{qi} = |q2_i - 2*q1_i + q0_i|$$

1. Calculate d_{pi} , calculate d_{qi} , for line i
2. if ($d_{pi} < thr1$)
3. {

Do normal filtering of line i of block A (e.g. two pixels from the block border)
4. }
5. else {
6. do not filter the second pixel from the block border of line i of block A (or do not filter any pixels at all on line i of block A)
7. }
8. if ($d_{qi} < thr2$)
9. {

Do normal filtering of line i of block B (e.g. two pixels from the block border)
10. }
11. else {
12. do not filter the second pixel from the block border of line i of block B (or do not filter any pixels at all on line i of block B)
13. }

3.4 Embodiment 4

Here in this embodiment is used as a combination of block based and line based asymmetric filter decisions.

$$\begin{aligned}d_{pi} &= |p2_i - 2*p1_i + p0_i| \\d_{qi} &= |q2_i - 2*q1_i + q0_i| \\d_p &= |p2_2 - 2*p1_2 + p0_2| + |p2_5 - 2*p1_5 + p0_5| \\d_q &= |q2_2 - 2*q1_2 + q0_2| + |q2_5 - 2*q1_5 + q0_5|\end{aligned}$$

1. Calculate d_p , calculate d_q ,
2. if ($d_p < thr1$)
3. {
 - For each line i
 - Calculate d_{pi} for line i
 - if ($d_{pi} < thr1$)
 - {
 - Do normal filtering of line i of block A (e.g. two pixels from the block border)
 - }
 - else {
 - do not filter the second pixel from the block border of line i of block A (or do not filter any pixels at all on line i of block A)
 - }
4. do not filter the second pixel from the block border (or do not filter any pixels at all)
5. if ($d_q < thr2$)
6. {
 - For each line
 - Calculate d_{qi} for line i
 - if ($d_{qi} < thr2$)

```

    {
        Do normal filtering of line i of block B (e.g. two pixels from the block
        border)
    }
    else {
        do not filter the second pixel from the block border of line i of block
        B (or do not filter any pixels at all on line i of block B)
    }
}
else {
7. do not filter the second pixel from the block border (or do not filter any
   pixels at all)
}

```

3.5 Advantages of the embodiments

The embodiments make the HEVC deblocking filtering adaptive to the structure on each side of block boundaries. The amount of filtering applied to one side of the block boundary can differ from the amount of filtering applied to the other side of the block boundary thus providing additional adaptation to the local structure. This improves the objective and subjective video quality. The embodiments do not require many additional computations, as the values for the decisions can be obtained on the previous steps when deciding whether to filter the block border. The embodiments also decrease the computational complexity, as filtering of the second pixel from the block border happens less frequently.

4 Abbreviations

HEVC – High Efficiency Video Coding, a new video compression standard under development jointly by two organizations (ITU-T's VCEG and ISO's MPEG).