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First Named Inventor/Applicant Name:	Andrey Norkin
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1		P33620- US1_2011-01-14_11-3021_Prov isional_Application.pdf	161909 dfff999c2e1337c830ccba1dc8eaf3aa12ce6 b33	yes	17
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Multipart Description/PDF files in .zip description

Document Description	Start	End
Transmittal of New Application	1	3
Specification	4	17

Warnings:

Information:

2	Fee Worksheet (PTO-875)	fee-info.pdf	29360 676a8d09e8ff4223a8ef6a963a8272de6ec2 c191	no	2
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET – Page 1 of 2

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Express Mail Label No. Transmitted Via EFS-Web

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):

Method, system, device, apparatus, computer program and computer program product for deblocking filters with at least one ramp preservation property

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

☐ Drawing(s) Number of Sheets _____

☒ Specification (e.g. description of the invention) Number of Pages 14

☐ CD(s), Number of CDs _____

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SIGNATURE /Sidney L. Weatherford, Reg No 45,602/

Date January 14, 2011

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Docket Number: P33620-US1

Method, system, device, apparatus, computer program and computer program product for deblocking filters with at least one ramp preservation property

TECHNICAL FIELD

The present description relates to a method, system, device, apparatus, computer program and computer program product for deblocking filters with at least one ramp preservation property.

BACKGROUND

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.

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 evaluation of several conditions. Filter decisions depends on macro block (MB) type, MV (Motion Vector) 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.

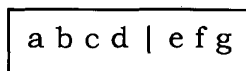


Figure 1 Pixel values across a vertical block boundary

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 value 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:

$$\text{abs}(d-e) < \text{thr}1/4.$$

Deblocking in HEVC draft

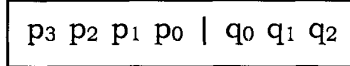


Figure 2 Pixel values across a vertical block boundary

In the draft HEVC (High Efficiency Video Coding) specification [1] “Test Model under Consideration”, ITU-T SG16 WP3 document, JCTVC-B205, 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:

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

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** $(|p_{3_i} - p_{0_i}| + |q_{0_i} - q_{3_i}|) < (\beta > 3)$

- **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.

A	$p3_0$	$p2_0$	$p1_0$	$p0_0$	$q0_0$	$q1_0$	$q2_0$	$q3_0$	B
	$p3_1$	$p2_1$	$p1_1$	$p0_1$	$q0_1$	$q1_1$	$q2_1$	$q3_1$	
	$p3_2$	$p2_2$	$p1_2$	$p0_2$	$q0_2$	$q1_2$	$q2_2$	$q3_2$	
	$p3_3$	$p2_3$	$p1_3$	$p0_3$	$q0_3$	$q1_3$	$q2_3$	$q3_3$	
	$p3_4$	$p2_4$	$p1_4$	$p0_4$	$q0_4$	$q1_4$	$q2_4$	$q3_4$	
	$p3_5$	$p2_5$	$p1_5$	$p0_5$	$q0_5$	$q1_5$	$q2_5$	$q3_5$	
	$p3_6$	$p2_6$	$p1_6$	$p0_6$	$q0_6$	$q1_6$	$q2_6$	$q3_6$	
	$p3_7$	$p2_7$	$p1_7$	$p0_7$	$q0_7$	$q1_7$	$q2_7$	$q3_7$	

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:

$$\Delta = \text{Clip}(-t_c, t_c, (13*(q0_i - p0_i) + 4*(q1_i - p1_i) - 5*(q2_i - p2_i) + 16) >> 5)) \quad i = 0, 7$$

$$p0_i = \text{Clip}_{0-255}(p0_i + \Delta) \quad i = 0, 7$$

$$q0_i = \text{Clip}_{0-255}(q0_i - \Delta) \quad i = 0,7$$

$$p1_i = \text{Clip}_{0-255}(p1_i + \Delta/2) \quad i = 0,7$$

$$q1_i = \text{Clip}_{0-255}(q1_i - \Delta/2) \quad i = 0,7$$

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.

$$p0_0 = \text{Clip}_{0-255}((p2_i + 2*p1_i + 2*p0_i + 2*q0_i + q1_i + 4) >> 3); \quad i = 0,7$$

$$q0_0 = \text{Clip}_{0-255}((p1_i + 2*p0_i + 2*q0_i + 2*q1_i + q2_i + 4) >> 3); \quad i = 0,7$$

$$p1_0 = \text{Clip}_{0-255}((p2_i + p1_i + p0_i + q0_i + 2) >> 2); \quad i = 0,7$$

$$q1_0 = \text{Clip}_{0-255}((p0_i + q0_i + q1_i + q2_i + 2) >> 2); \quad i = 0,7$$

$$p2_0 = \text{Clip}_{0-255}((2*p3_i + 3*p2_i + p1_i + p0_i + q0_i + 4) >> 3); \quad i = 0,7$$

$$q2_0 = \text{Clip}_{0-255}((p0_i + q0_i + q1_i + 3*q2_i + 2*q3_i + 4) >> 3); \quad i = 0,7$$

SUMMARY

One problem with the deblocking in HEVC is that the weak filter that is used there does not have good low-pass characteristics. One can see that the first and the second filter from the block border are modified by adding (or subtracting) the Δ and $\Delta/2$ respectively. Such a filter cannot remove high frequencies that can appear near the block border and cannot remove ringing. Moreover, the frequency characteristics of the filter in HEVC show slight amplifications of higher frequencies, which can result in worse RD-performance of the coder.

An improved deblocking filter for HEVC standard is hereinafter proposed which has better frequency characteristics than the current filter in HEVC. The proposed filter does not modify the ramp but smoothes the step function. A ramp can be described as linearly increasing or decreasing pixel values (e.g. 10 20 30 40). A step function can be described as a step increase or decrease in pixel values (e.g 10 10 20 20).

At least one embodiment produce an offset (also called delta or Δ) for the pixels closest to the block border (p_0 and q_0) with the formula that produces approximate zero when applied to the ramp and which produces a value towards the middle when applied to the step function.

The filters for the coefficients that stand at the second position from the block border (p_1 and q_1) are produced by using a combination of the delta obtained at the first step and a symmetrical low-pass filter.

This concept can also be generalized for the filters modifying more than 2 pixels from the block border. For example, the third pixel from the block border can be obtained using a combination of the delta for the second (or the first) pixel and a symmetrical low-pass filter. Longer filters are also possible.

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.

A filter according to at least one of the embodiments described below is a low-pass filter on all the filter positions (p_0, p_1, q_0, q_1). When applied to the ramp signal, it would not modify it, since Δ , Δ_p and Δ_q will all be equal to zero. When applied to the step function (a deblocking artefact), the filter would smooth it.

Unlike the H.264 deblocking, the proposed filter according to at least one of the below described embodiments would not modify the signal that has the shape of the ramp. This is an advantageous feature for HEVC, as the HEVC standard draft allows filtering of the blocking artefacts when the surfaces on both sides of the block border remind ramps (or inclined plane). Unlike the current HEVC filter, the proposed filter according to at least one of the below embodiments is a low-pass filter in the second pixel and would attenuate small ripples on the sides of the block border.

Moreover, unlike the HEVC standard draft **Error! Reference source not found.**, the deltas for the second pixels p_1 and q_1 on both sides of the block border can have different value that allows better local adaptation.

DETAILED DESCRIPTION

The disclosure below covers various embodiments described in detail. However it is to be understood that they are not intended to limit the spirit and scope of the disclosure to the specific forms disclosed. Five embodiments will hereinafter be disclosed.

Embodiment 1

In a first embodiment, the pixel values are updated by the proposed filter by using the following calculations:

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

$$p_0' = p_0 + \Delta$$

$$q_0' = q_0 - \Delta$$

However, another formula that generates Δ can be used that produces approximate zero when applied to the ramp and which smoothes the step function.

The Δ 's for the second pixel offset is calculated by using Δ from the first step and a low-pass filter with symmetrical coefficients. The example of such a filter is shown below.

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

$$p_1' = p_1 + \Delta_p$$

$$\Delta_q = (q_0 + q_2 - 2 \cdot q_1 - 2 \cdot \Delta) / 4;$$

$$q_1' = q_1 + \Delta_q$$

The proposed filter is a low-pass filter on all the filter positions (p_0, p_1, q_0, q_1). When applied to the ramp signal, it would not modify it, since Δ, Δ_p and Δ_q will all be equal to zero. When applied to the step function (a deblocking artefact), the filter would smooth it.

Unlike the H.264 deblocking, the proposed filter would not modify the ramp. This is a desirable feature for HEVC, as the HEVC standard allows filtering the blocking artefacts when the surfaces on both sides of the block border remain ramps (or inclined planes). Unlike the current HEVC filter, the proposed filter is a low-pass filter and would smooth the small ripples on the sides of the block border.

Embodiment 2

A second embodiment can also be applied to create filters with larger number of pixels to be changed. The example of a filter that changes 3 pixels from each side of the boundary can be found here:

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

$$p_0' = p_0 + \Delta$$

$$q_0' = q_0 - \Delta$$

$$\Delta_{p1} = (p_0+p_2-2*p_1+2*\Delta)/4;$$

$$p_1' = p_1 + \Delta_{p1}$$

$$\Delta_{q1} = (q_0+q_2-2*q_1-2*\Delta)/4;$$

$$q_1' = q_1 + \Delta_{q1}$$

$$\Delta_{p2} = (p_1+p_3-2*p_2+2*\Delta_{q1})/4;$$

$$p_2' = p_2 + \Delta_{p2}$$

$$\Delta_{q2} = (q_1+q_3-2*q_2+2*\Delta_{p2})/4;$$

$$q_2' = q_2 + \Delta_{q2}$$

Embodiment 3.

Another example of the filter is given below as a third embodiment, where one can use a more strong low-pass filter with combination of delta from the first pixel.

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

$$p_0' = p_0 + \Delta$$

$$q_0' = q_0 - \Delta$$

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

$$p_1' = p_1 + \Delta_p$$

$$\Delta_q = (q_0 + q_2 - 2 * q_1 - \Delta) / 2;$$

$$q_1' = q_1 + \Delta_q$$

Embodiment 4

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

```
delta = Clip3(-tc, tc, (9*(q0-p0) -3*(q1-p1) + 8)>>4 );
piSrc[-iOffset] = Clip((p0+delta));
piSrc[0] = Clip((q0-delta));

delta1 = Clip3(-tc2, tc2, ((p2+p0-((p1-delta)<<1)+2)>>2));
delta2 = Clip3(-tc2, tc2, ((q2+q0-((q1+delta)<<1)+2)>>2));

piSrc[-iOffset*2] = Clip((p1+delta1));
piSrc[iOffset] = Clip((q1+delta2));
```

Another way to calculate the delta1 and delta 2 are given in the text below.

```
delta = Clip3(-tc, tc, (9*(q0-p0) -3*(q1-p1) + 8)>>4 );
piSrc[-iOffset] = Clip((p0+delta));
piSrc[0] = Clip((q0-delta));

delta1 = Clip3(-tc2, tc2, (((p2+p0+1)>>1) - p1+delta+1)>>1));
delta2 = Clip3(-tc2, tc2, (((q2+q0+1)>>1) - q1-delta+1)>>1));
```

```
piSrc[-iOffset*2] = Clip((p1+delta1));
piSrc[ iOffset] = Clip((q1+delta2));
```

Below is another way to reduce the amount of calculations when filtering.

```
delta = Clip3(-tc, tc, (9*(q0-p0) -3*(q1-p1) + 8)>>4 );
piSrc[-iOffset] = Clip((p0+delta));
piSrc[0] = Clip((q0-delta));

delta1 = Clip3(-tc2, tc2, (( (p2+p0+1)>>1)- p1+delta)>>1));
delta2 = Clip3(-tc2, tc2, (( (q2+q0+1)>>1)- q1-delta)>>1));

piSrc[-iOffset*2] = Clip((p1+delta1));
piSrc[ iOffset] = Clip((q1+delta2));
```

Embodiment 5

Here follows a fifth embodiment similar to the first embodiment. In the fifth embodiment the idea is to have the computations of the deltas independent of each other, for example through a calculation according to the following:

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

$$p_0' = p_0 + \Delta$$

$$q_0' = q_0 - \Delta$$

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

$$p_1' = p_1 + \Delta_p + \Delta/2$$

$$\Delta_q = (q_0+q_2-2*q_1)/4;$$

$$q_1' = q_1 + \Delta_q - \Delta/2$$

All embodiments described above may be appropriate as methods of a video encoder and/or video decoder. The video decoder can be implemented preferably in hardware but also in software. The same holds for the video encoder. The video encoder and/or the video decoder may be implemented in a user equipment (UE) such as a mobile telephone, tablet, desktop, netbook, personal video recorder, multimedia player, video streaming server, set-top box and TV. The encoder and/or decoder may also be implemented in a network device being or belonging to a network node in a communications network between a sending unit and a receiving UE. Such a network device may be a device for converting video according to one video coding standard to another video coding standard, for example if it has been established that the receiving UE is only capable or prefers another video coding standard than the one sent from the sending unit.

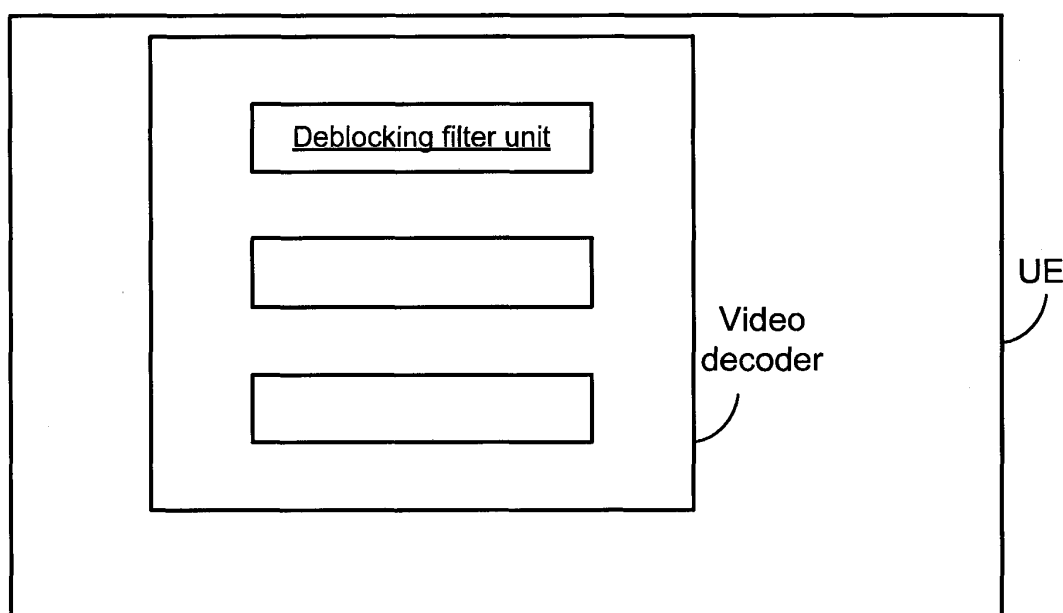


Fig. 4

Fig 4 shows schematically an embodiment of a UE. The UE here comprises a decoder. determining unit 720 that performs the step 610;

- deblocking filter unit for HEVC standard for smoothing a step function and generating an offset (delta) for pixels being closest to a block border, which could be a vertical border or a horizontal border) with a calculation according to any one

of the five embodiments described above that produces approximate zero when applied to the ramp and which produces a value towards the middle when applied to the step function.

Although the video decoder disclosed in Fig 4 has been disclosed as physically separate unit in the computer UE, and may be comprised in a special purpose circuits such as one or more ASICs (Application Specific Integrated Circuits), the decoder covers embodiments of the UE or other type of device/apparatus where some parts of the decoder and deblocking filter unit are implemented as computer program modules running on general purpose processor. Such an embodiment is disclosed in conjunction with Fig 5.

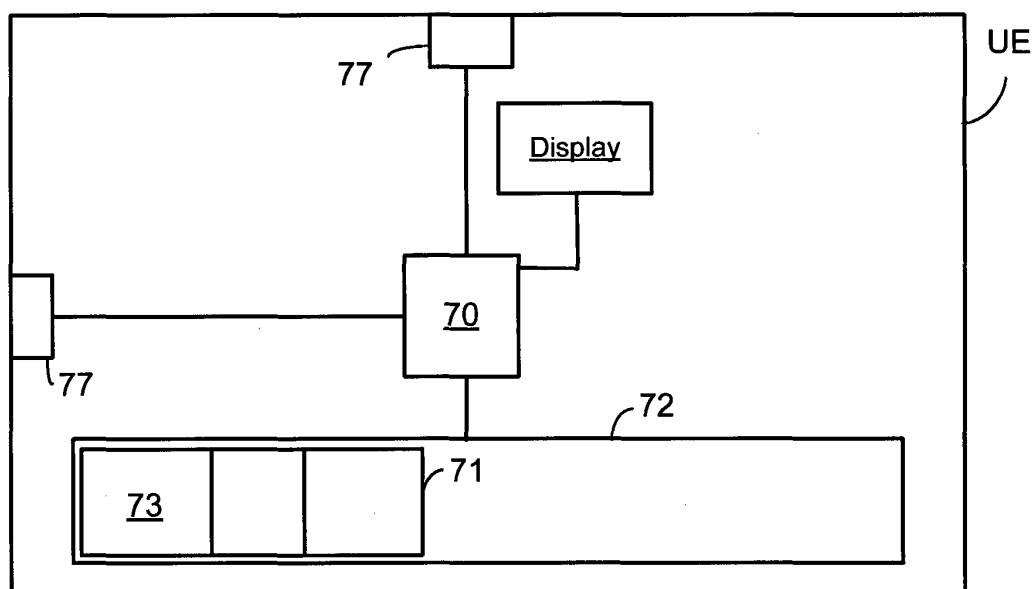


Fig 5

Fig 5 schematically shows an embodiment of the UE, which also can be an alternative way of disclosing an embodiment of the UE illustrated in Fig 4. Comprised in the UE is here a processing unit, e.g. with a DSP (Digital Signal Processor). The processing unit 70 can be a single unit or a plurality of units for performing different steps of the decoder. The UE also comprises the input unit 77 for receiving video data directly or indirectly from a sending unit. The processing unit 70 is here also connected to a display integrated in or connected to the UE.

Furthermore the UE here comprises at least one computer program product 72 in the form of a memory, e.g. an EEPROM (Electrically Erasable Programmable Read-only Memory, a flash memory and a disk drive. The computer program product 72 comprises a computer program 71, which comprises code means which when run on the UE causes the UE to perform the steps of the deblocking filter unit describe above in conjunction with Fig 4 or any of the embodiments one to five. Hence in the exemplary embodiments described, the code means in the computer program 71 of the UE comprises a deblocking filter module module 73 for for smoothing a step function and generating an offset (delta) for pixels being closest to a block border, which could be a vertical border or a horizontal border) with a calculation according to any one of the five embodiments described above that produces approximate zero when applied to the ramp and which produces a value towards the middle when applied to the step function.

In another embodiment the processing unit 70 comprises a decoder and encoder circuit with an integrated deblocking function corresponding to the deblocking filter unit.