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| *Title:* | **Non-CE6.d: Intra Prediction With Selective Secondary Boundary** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Proposal | | |
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# Abstract

This contribution proposes to improve the harmonized intra prediction method with secondary boundary that is studied in CE6.d by selectively applying prediction from the secondary boundary. The “All Intra HE” average BD-rate for class F sequences is improved from 0.2% to -0.2%.

# Problem Statement

The HEVC Working Draft version 4 (WD4) specifies the following intra prediction modes for the luma component: planar, DC, and up to 33 directional modes depending on the intra PU size. The DC prediction filtering method [1] and simplification [2] apply filtering across the boundary of the DC predicted PU.

At the 6th JCT-VC meeting (July 2011) in Torino, Italy, at least four contributions were proposed that process the boundaries of the intra predicted PU with filters, gradient-based prediction, and bi-directional prediction. The following proposals are the subject of the CE6.d experiment on “Intra prediction with secondary boundary” [7]. [3] proposes two techniques to improve directional intra prediction: gradient-based prediction and bi-directional prediction. In gradient-based prediction the difference between two reference boundary samples is computed (interpolation may be required), weighted, and added to at least one column or row along the intra PU boundary, depending on horizontal or vertical prediction. In bi-directional prediction the reference samples on both ends of the direction are used (interpolation may be required), and the reference sample on the secondary boundary is weighted and added to the predicted intra PU sample. [4] proposes adding the weighted gradient between two reference samples to at least one column or row along the intra PU boundary for the vertical and horizontal prediction modes. [5] applies a filter across the boundary of planar prediction mode and applies a diagonal 2-tap filter to the secondary boundary depending on the intra prediction direction. [6] also applies a diagonal 2-tap filter across the secondary boundary depending on the intra prediction direction.

The report on CE6.d [8] proposes the harmonization of the proposals above. This harmonized solution is also known as the result from “Test 13” in [9]. Table 1 enumerates the BD-rate results according to the common test conditions for HM4. The average gain is -0.7% for classes A-E. Table 2 enumerates the BD-rate results including class F sequences. The average gain including class F is -0.6% for “All Intra HE” and -0.5% for “All Intra LC”. The reason for the smaller gain is class F, which has an average loss of 0.2%, mainly due to the sequences “ChinaSpeed” and “SlideEditing”, which have losses of respectively about 0.5% and 1%.

This contribution proposes “intra prediction with selective secondary boundary” in order to turn the class F loss into a gain.

Table BD-rate results for CE6.d harmonized solution, excluding class F

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra HE** | | | **All Intra LC** | | |
|  | Y | U | V | Y | U | V |
| Class A | -0.9% | -0.8% | -0.9% | -0.8% | -1.0% | -1.1% |
| Class B | -0.6% | -0.6% | -0.6% | -0.6% | -0.8% | -0.8% |
| Class C | -0.6% | -0.6% | -0.7% | -0.7% | -0.8% | -0.7% |
| Class D | -0.7% | -0.6% | -0.7% | -0.7% | -0.7% | -0.7% |
| Class E | -0.8% | -0.7% | -0.9% | -0.7% | -0.9% | -0.9% |
| **Overall** | -0.7% | -0.7% | -0.7% | -0.7% | -0.8% | -0.8% |
|  | -0.7% | -0.7% | -0.7% | -0.7% | -0.8% | -0.9% |

Table BD-rate results for CE6.d harmonized solution, including class F

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra HE** | | | **All Intra LC** | | |
|  | Y | U | V | Y | U | V |
| Class A | -0.9% | -0.8% | -0.9% | -0.8% | -1.0% | -1.1% |
| Class B | -0.6% | -0.6% | -0.6% | -0.6% | -0.8% | -0.8% |
| Class C | -0.6% | -0.6% | -0.7% | -0.7% | -0.8% | -0.7% |
| Class D | -0.7% | -0.6% | -0.7% | -0.7% | -0.7% | -0.7% |
| Class E | -0.8% | -0.7% | -0.9% | -0.7% | -0.9% | -0.9% |
| Class F | 0.2% | 0.1% | 0.1% | 0.2% | -0.1% | -0.2% |
| **Overall** | -0.6% | -0.6% | -0.6% | -0.5% | -0.7% | -0.7% |
|  | -0.6% | -0.6% | -0.6% | -0.5% | -0.7% | -0.7% |

# Selective Secondary Boundary Intra Prediction

This contribution proposes to detect the cases that result in BD-rate losses for intra prediction with secondary boundary. If the detection is positive, the prediction from the secondary boundary may be partially or entirely disabled in order to improve BD-rate performance.

Figure 1 illustrates computing relationships between the reference boundary samples based on Laplacians. For directional intra prediction modes, the secondary boundary is defined as the top intra PU boundary in case of horizontal directions (HOR-7 to HOR+8), and as the side (left) intra PU boundary for vertical modes (VER-8 to VER+8). The top reference boundary samples are denoted by TR[i] (i=0…N), and the side reference boundary samples by SR[i] (i=0…N). The intra PU samples are denoted by P[k,l] (k,l=0…N). The following pseudo-code illustrates the computation of the relationships between the reference boundary samples based on Laplacians in case of directional intra prediction modes:

* IF (horizontal directional mode) THEN
  + Value = MAX( | TR[N-2] -2\*TR[N-1] + TR[N] |, | TR[N-3] -2\*TR[N-2] + TR[N-1] | )
* IF (vertical directional mode) THEN
  + Value = MAX( | SR[N-2] -2\*SR[N-1] + SR[N] |, | SR[N-3] -2\*SR[N-2] + SR[N-1] | )
* IF ( Value < Threshold ) THEN { Enable secondary boundary filtering technique } ELSE { Disable }

The conditions are applied to the following directional intra modes: VER+4…VER+8, VER-4…VER-8, HOR+4…HOR+8, HOR-4…HOR-7. The conditions are also applied to multiple line/column prediction for the modes VER, HOR, VER+8, HOR+8. There are three threshold values: 24 (VER+4…VER+7, VER-4…VER-8, HOR+4…HOR+7, HOR-4…HOR-7), 128 (multi line VER, HOR, VER+8, HOR+8), 256 (VER+8, HOR+8).

TR[N-2]

TR[N-1]

TR[N-3]

(0,0)

(N,0)

(i,j)

(0,N)

(N,N)

Side reference (SR) boundary samples (column)

Reference samples for computing Laplacians

TR[N-1]

TR[N]

TR[N-2]

SR[N-2]

SR[N-1]

SR[N-3]

SR[N-1]

SR[N]

SR[N-2]

Top reference (TR) boundary samples (row)

Figure Intra PU of size NxN samples that is predicted using a horizontal (top figures) or vertical (bottom figures) directional mode. The top (TR) or side (SR) reference boundary samples used in the computation of the Laplacians are shaded.

# Results

The BD-rate results in Table 3 and Table 4 were obtained according to the HM4 common test conditions (JCTVC-F900). The encoding times are measured in a variable computing environment, while the decoding times are measured on a single CPU.

The BD-rate of class F is -0.2% for “All Intra HE” and 0.0% for “All Intra LC”. The BD-rates for the individual class F sequences are enumerated in Table 5. The encoding and decoding times are comparable with the HM4 anchor.

Table BD-rate results for intra prediction with selective secondary boundary, including class F

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra HE** | | | **All Intra LC** | | |
|  | Y | U | V | Y | U | V |
| Class A | -0.9% | -0.8% | -0.8% | -0.8% | -1.0% | -1.1% |
| Class B | -0.6% | -0.6% | -0.6% | -0.6% | -0.8% | -0.7% |
| Class C | -0.6% | -0.6% | -0.6% | -0.7% | -0.8% | -0.7% |
| Class D | -0.6% | -0.6% | -0.6% | -0.7% | -0.6% | -0.7% |
| Class E | -0.8% | -0.7% | -0.7% | -0.7% | -0.9% | -1.0% |
| Class F | -0.2% | -0.4% | -0.3% | 0.0% | -0.2% | -0.3% |
| **Overall** | -0.6% | -0.6% | -0.6% | -0.6% | -0.7% | -0.7% |
|  | -0.6% | -0.6% | -0.6% | -0.6% | -0.7% | -0.8% |
| Enc Time[%] | 101% | | | 99% | | |
| Dec Time[%] | 100% | | | 101% | | |

Table BD-rate results for intra prediction with selective secondary boundary, excluding class F

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra HE** | | | **All Intra LC** | | |
|  | Y | U | V | Y | U | V |
| Class A | -0.9% | -0.8% | -0.8% | -0.8% | -1.0% | -1.1% |
| Class B | -0.6% | -0.6% | -0.6% | -0.6% | -0.8% | -0.7% |
| Class C | -0.6% | -0.6% | -0.6% | -0.7% | -0.8% | -0.7% |
| Class D | -0.6% | -0.6% | -0.6% | -0.7% | -0.6% | -0.7% |
| Class E | -0.8% | -0.7% | -0.7% | -0.7% | -0.9% | -1.0% |
| **Overall** | -0.7% | -0.6% | -0.6% | -0.7% | -0.8% | -0.8% |
|  | -0.7% | -0.6% | -0.7% | -0.7% | -0.8% | -0.8% |
| Enc Time[%] | 101% | | | 99% | | |
| Dec Time[%] | 99% | | | 101% | | |

Table BD-rate for class F sequences

|  |  |  |  |
| --- | --- | --- | --- |
| Class F Sequence | Y | U | V |
| BasketballDrillText | -0.5% | -0.5% | -0.6% |
| ChinaSpeed | 0.2% | 0.1% | 0.0% |
| SlideEditing | 0.0% | -0.2% | -0.1% |
| SlideShow | -0.5% | -1.0% | -0.7% |
|  | -0.2% | -0.4% | -0.3% |

# Conclusion

This contribution presented an improvement to the harmonized intra prediction method with secondary boundary that is studied in CE6.d. It is proposed to selectively apply the prediction from the secondary boundary by computing relationships between samples along the secondary boundary. The prediction is selectively enabled by applying thresholding. It is demonstrated that the average BD-rate for the class F sequences can be improved from 0.2% to -0.2% for “All Intra HE” and from 0.2% to 0.0% for “All Intra LC”.

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