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| Title: | **Non-CE6a: Border-adaptive subsampling for LM mode** | | |
| Status: | Input Document to JCT-VC | | |
| Purpose: | Proposal | | |
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# Abstract

In JCTVC-G358, additional luma-based modes were presented to improve coding efficiency. Also, in JCTVC-G126, simplifications to the OLS computations of the original luma-based modes were also presented. The present contribution merges the 2 concepts to evaluate the cumulative improvements. It is reported that the technique brings up to 1.3% and 1.2% BDR gains in AIHE and 1.9% and 2.0% in AIHE 10 bits respectively for U and V, while reducing the encoding runtime by up to 1% and the decoding runtime by 2%.

# Introduction

## Chroma from luma prediction mode

This mode predicts chroma samples of the current block based on corresponding reconstructed luma samples in the following linear relationship:

 (1)

where  is obtained by downsampling reconstructed luma samples.

Parameters  and are derived from reconstructed samples around the current block. The equation used for calculating  (and ) is the ordinary least square (OLS) solution:



whereand indicate reconstructed chroma samples and filtered luma samples around the target block, indicates total samples number of neighboring data. In HM-5.0, *I* can be 4, 8 or 16 and larger blocks require more computation for calculation of  and  parameters. For a target *N×N* chroma block, assuming intra padding, total involved samples number is *2N*.



Figure 1 : Neighboring samples used for parameters derivation in LM mode (L shape template)

## JCTVC-G358 : additional luma-based modes

### Presentation

In the JCTVC-G358 proposal, two new modes (LML and LMA) for chroma intra prediction from luma are proposed. Both of these two methods have a prediction process similar to the LM mode, except that the neighboring samples sets used to determine parameters and are from different locations, so as to match object continuities. The proposal then reports various integrations to the list of chroma intra prediction modes.

### LML mode and LMA mode.

When LML mode is used, the chroma samples are predicted from reconstructed luma samples in the same block according to equation (1). The parametersand in equation (1) are derived from the block neighborhoods, as Figure 2 below shows. For an NxN chroma block, only 2N samples from left and down left neighboring locations are used as the set. The calculation ofandare the same as LM mode.



Figure 2 : Neighboring samples used for parameters derivation in LML mode

Similarly, when LMA mode is used, only above and above right neighboring samples are used to derive parameters and, as Figure 3 shows. For an NxN chroma block, 2N samples are used as the set. The calculation of andare the same as LM mode.



Figure 3 : Neighboring samples used for parameters derivation in LMA mode

## JCTVC-G126 : additional luma-based modes

The contribution proposes to reduce computational complexity by subsampling and  before passing it on to OLS:

Table below shows comparison of number of multiplications and corresponding BD-Rate results for sub-sampling of reference samples before use in calculation of  and . HM-4.0 reference software with bug-fix for alpha renormalization was used in simulations.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Number of multiplications per block for calculating alpha and beta | | | All Intra HE | | | All Intra LC | | |
| Subsampling factor | 4x4 | 8x8 | 16x16 | Y | U | V | Y | U | V |
| HM-4.0 | 16 | 32 | 64 |  |  |  |  |  |  |
| 1:2 for 16x16 | 16 | 32 | 32 | 0.0% | 0.2% | 0.1% | 0.0% | 0.1% | 0.0% |
| 1:2 for 8x8, 16x16 | 16 | 16 | 32 | 0.1% | 0.5% | 0.4% | 0.1% | 0.5% | 0.3% |
| 1:2 for 8x8, 1:4 for 16x16 | 16 | 16 | 16 | 0.1% | 0.8% | 0.5% | 0.1% | 0.7% | 0.3% |

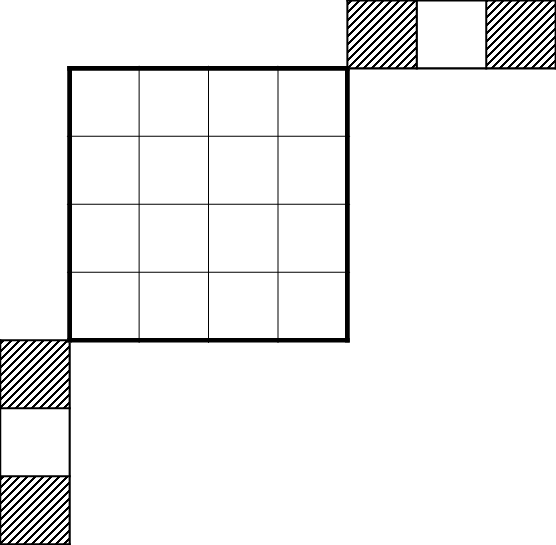
Table 1 : Coding efficiency results for various decimation ratios

It was however reported that it does not reduce the worst case, which is the 4x4 blocks.

# Proposal description

## Additional luma-based modes

In a similar fashion to JCTVC-G358, the current contribution uses two luma-based chroma prediction modes. Let us define dx and dy the offsets respectively in the top border from its start and in the left border from its start. In each case, 1 out of 2 pixels is used. Next figure helps defining these dx and dy values by illustrating a 4x4 block:



dx

dy

Figure 4 : Definitions for the description of the 2 luma-based chroma prediction modes

As one already knows, the borders may be filled using the padding process, resulting in the outer parts (respectively dx>N-1 and dy>N-1 for a NxN block) being filled by the last sample in the inner parts (respectively dx=N-1 and dy=N-1 for a NxN block) when outer part samples are not available. This availability depends on the block size and the CU index.

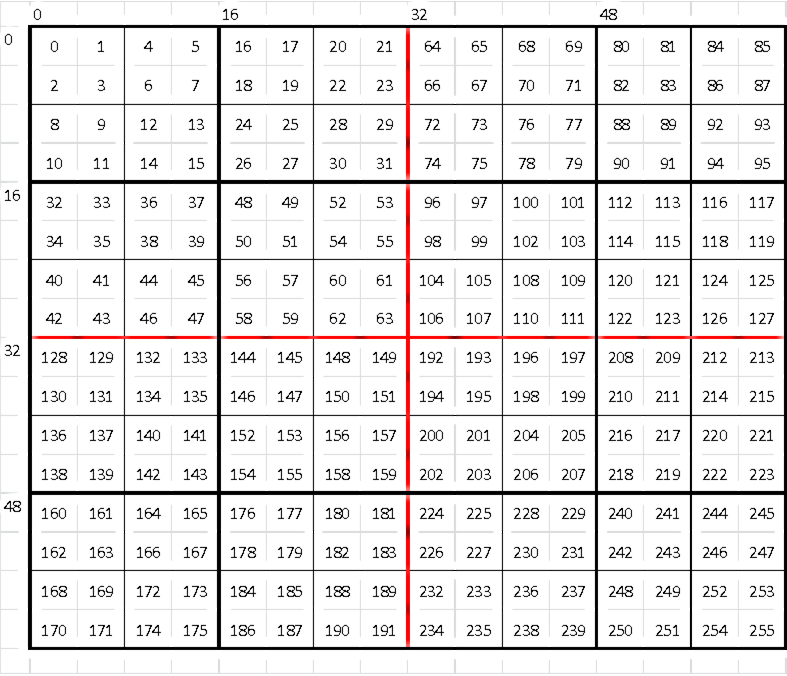


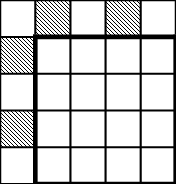
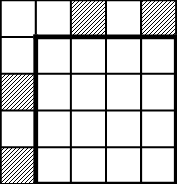
Figure 5 : Block Z scan order indexes

Using Figure 1 above, we can see that the following CUs have their outer borders filled with those last samples based on their Z-order index:

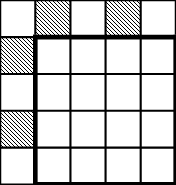
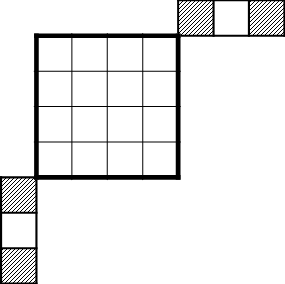
* 4x4: 3, 7, 11, 15, …
* 8x8: 12, 28, 44, 60, …
* 16x16: 48, 112, 176, 240

The contribution sets as first LM mode, called LM1, the mode using dx=dy=0. Then, 2 scenarios exist for a NxN block of Z-order index index:

* Scenario 1, where the second mode LM2 uses dx=dy=1, which for 4x4 blocks is:



* Scenario 2, where the second modes LM2 uses:
  + If index is in the above list, dx=dy=1 (therefore, LM2 is equivalent to scenario 1’s LM2)
  + Otherwise, dx=dy=N



Scenario 1 has the advantage of never accessing outer samples.

## Mode coding

The new list of modes, together with their corresponding codewords, becomes:

|  |  |
| --- | --- |
| Chroma intra prediction mode | Codewords |
| DM | 0 |
| LM1 | 10 |
| LM2 | 110 |
| DC | 11110 |
| Planar | 11111 |
| Vertical | 11111 |

Table 2 : List of chroma prediction modes and their codewords

In addition, when DM is one of DC, Planar or Vertical, an alternate mode, Horizontal, replaces it.

# Results

We report the results of AIHE (without class F), AIHE Full (class F and 10bits class A sequences included) and finally, AIHE 10 bits (class F and 10bits class A sequences included). Those were cross-checked by Sony in JCTVC-H0206.

## Scenario 1

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra HE** | | | **All Intra HE (Full)** | | | **All Intra HE-10 (Full)** | | |
|  | Y | U | V | Y | U | V | Y | U | V |
| Class A | 0.0% | -0.2% | -0.2% | 0.0% | -2.3% | -2.2% | 0.0% | -1.7% | -1.8% |
| Class B | 0.0% | -0.5% | -0.5% | 0.0% | -0.5% | -0.5% | 0.1% | -0.2% | -0.4% |
| Class C | 0.1% | -0.7% | -0.8% | 0.1% | -0.7% | -0.8% | 0.1% | -0.4% | -0.6% |
| Class D | 0.1% | -0.4% | -0.5% | 0.1% | -0.4% | -0.5% | 0.1% | -0.4% | -0.5% |
| Class E | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.2% | 0.1% |
| Class F | 0.1% | -0.8% | -1.0% | 0.1% | -0.8% | -1.0% | 0.1% | -0.7% | -1.0% |
| **Overall** | 0.1% | -0.4% | -0.5% | 0.0% | -0.8% | -0.9% | 0.1% | -0.5% | -0.7% |
|  | 0.1% | -0.4% | -0.4% | 0.0% | -0.8% | -0.9% | 0.1% | -0.6% | -0.7% |
| Enc Time[%] | 99% | | | 99% | | | 100% | | |
| Dec Time[%] | 98% | | | 98% | | | 97% | | |

Table 3 : Results for scenario 1

The details are available in the provided “JCTVC-H0176\_scenario\_1.xls” file.

## Scenario 2

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra HE** | | | **All Intra HE (Full)** | | | **All Intra HE-10 (Full)** | | |
|  | Y | U | V | Y | U | V | Y | U | V |
| Class A | -0.1% | -1.2% | -1.0% | -0.1% | -5.1% | -5.7% | -0.1% | -5.0% | -5.8% |
| Class B | 0.0% | -1.6% | -1.1% | 0.0% | -1.6% | -1.1% | 0.0% | -1.5% | -1.2% |
| Class C | 0.0% | -1.2% | -1.3% | 0.0% | -1.2% | -1.3% | 0.0% | -1.1% | -1.3% |
| Class D | 0.0% | -1.0% | -1.2% | 0.0% | -1.0% | -1.2% | 0.0% | -1.1% | -1.2% |
| Class E | 0.0% | -1.3% | -1.1% | 0.0% | -1.3% | -1.1% | 0.0% | -1.3% | -1.1% |
| Class F | 0.1% | -1.2% | -1.3% | 0.1% | -1.2% | -1.3% | 0.1% | -1.2% | -1.4% |
| **Overall** | 0.0% | -1.3% | -1.2% | 0.0% | -1.9% | -2.0% | 0.0% | -1.9% | -2.0% |
|  | 0.0% | -1.3% | -1.1% | 0.0% | -1.9% | -1.9% | 0.0% | -1.9% | -2.0% |
| Enc Time[%] | 100% | | | 100% | | | 100% | | |
| Dec Time[%] | 98% | | | 98% | | | 97% | | |

Table 4 : Results for scenario 2

The details are available in the provided “JCTVC-H0176\_scenario\_2.xls” file.

# Conclusion

We reported results for a combination of tools which reportedly achieves a halved complexity at the decoder for the OLS computation, while achieving BDR coding gains of more than 1.2% on the chroma channels and the AIHE 8 bits configuration, and almost 2% on the full AIHE 10 bits configuration. This translates in often 1% gain in encoder runtime and 2% in decoder runtime. Also, algorithmically, the worst-case (and, in fact, any case) complexity for the OLS computation has been halved. It is therefore recommended to incorporate these tools in the HEVC design.

# Annex

This section presents informative results about the integration of JCTVC-G244 with scenarios 1 and 2, as well as evaluates the results of JCTVC-G358 in its 6 modes configuration, when borders are subsampled using a 1:2 ratio.

## 1:2 subsampling applied to HM5.0

A fairer comparison for scenarios 1 and 2 are the results when the same subsampling is applied to HM5.0, of which the results are:

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra HE** | | | **All Intra HE (Full)** | | | **All Intra HE-10 (Full)** | | |
|  | Y | U | V | Y | U | V | Y | U | V |
| Class A | 0,0% | 0,5% | 0,4% | 0,1% | 0,5% | 0,3% | 0,1% | 0,7% | 0,2% |
| Class B | 0,1% | 0,4% | 0,3% | 0,1% | 0,4% | 0,3% | 0,1% | 0,6% | 0,3% |
| Class C | 0,2% | 0,8% | 1,1% | 0,2% | 0,8% | 1,1% | 0,2% | 0,9% | 1,1% |
| Class D | 0,2% | 0,9% | 0,8% | 0,2% | 0,9% | 0,8% | 0,2% | 0,8% | 0,7% |
| Class E | 0,0% | 0,3% | 0,4% | 0,0% | 0,3% | 0,4% | 0,0% | 0,2% | 0,2% |
| Class F | 0,5% | 1,0% | 1,2% | 0,5% | 1,0% | 1,2% | 0,5% | 1,0% | 1,1% |
| **Overall** | 0,1% | 0,6% | 0,6% | 0,2% | 0,7% | 0,7% | 0,2% | 0,7% | 0,6% |
|  | 0,1% | 0,6% | 0,6% | 0,2% | 0,7% | 0,7% | 0,2% | 0,7% | 0,6% |
| Enc Time[%] | 99% | | | 99% | | | 99% | | |
| Dec Time[%] | 101% | | | 101% | | | 100% | | |

## Scenario 1 and JCTVC-G.244

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra HE** | | | **All Intra HE (Full)** | | | **All Intra HE-10 (Full)** | | |
|  | Y | U | V | Y | U | V | Y | U | V |
| Class A | 0.0% | -3.0% | -2.7% | 0.0% | -11.4% | -13.4% | 0.0% | -11.6% | -14.0% |
| Class B | 0.0% | -2.4% | -1.9% | 0.0% | -2.4% | -1.9% | 0.1% | -2.1% | -2.0% |
| Class C | 0.0% | -2.0% | -2.2% | 0.0% | -2.0% | -2.2% | 0.1% | -1.8% | -2.2% |
| Class D | 0.0% | -1.6% | -2.0% | 0.0% | -1.6% | -2.0% | 0.1% | -1.6% | -1.9% |
| Class E | 0.0% | -2.5% | -2.0% | 0.0% | -2.5% | -2.0% | 0.0% | -2.8% | -2.0% |
| Class F | 0.0% | -1.4% | -1.8% | 0.0% | -1.4% | -1.8% | 0.0% | -1.3% | -1.8% |
| **Overall** | 0.0% | -2.2% | -2.1% | 0.0% | -3.5% | -3.9% | 0.0% | -3.5% | -4.0% |
|  | 0.0% | -2.2% | -2.1% | 0.0% | -3.5% | -3.9% | 0.0% | -3.5% | -3.9% |
| Enc Time[%] | 101% | | | 100% | | | 100% | | |
| Dec Time[%] | 99% | | | 99% | | | 98% | | |

The details are available in the provided “JCTVC-H0176\_scenario\_1+G244.xls” file.

## Scenario 2 and JCTVC-G.244

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra HE** | | | **All Intra HE (Full)** | | | **All Intra HE-10 (Full)** | | |
|  | Y | U | V | Y | U | V | Y | U | V |
| Class A | -0.1% | -3.7% | -3.2% | 0.0% | -12.5% | -14.8% | 0.0% | -12.7% | -15.4% |
| Class B | 0.0% | -2.9% | -2.0% | 0.0% | -2.9% | -2.0% | 0.0% | -2.8% | -2.2% |
| Class C | -0.1% | -2.3% | -2.4% | -0.1% | -2.3% | -2.4% | 0.0% | -2.1% | -2.4% |
| Class D | 0.0% | -2.0% | -2.2% | 0.0% | -2.0% | -2.2% | 0.0% | -2.0% | -2.2% |
| Class E | 0.0% | -3.2% | -2.7% | 0.0% | -3.2% | -2.7% | 0.0% | -3.6% | -2.8% |
| Class F | 0.0% | -1.3% | -1.6% | 0.0% | -1.3% | -1.6% | 0.1% | -1.2% | -1.6% |
| **Overall** | 0.0% | -2.7% | -2.4% | 0.0% | -4.0% | -4.2% | 0.0% | -4.0% | -4.4% |
|  | 0.0% | -2.7% | -2.4% | 0.0% | -4.0% | -4.2% | 0.0% | -4.0% | -4.4% |
| Enc Time[%] | 101% | | | 101% | | | 101% | | |
| Dec Time[%] | 99% | | | 99% | | | 97% | | |

The details are available in the provided “JCTVC-H0176\_scenario\_2+G244.xls” file.

## JCTVC-G358 and decimation

We used the software as released in CE6a, where JCTVC-G358 implementation (Section 3.2) adds its 2 LML and LMA modes to the 6 already existing modes.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra HE** | | | **All Intra HE (Full)** | | | **All Intra HE-10 (Full)** | | |
|  | Y | U | V | Y | U | V | Y | U | V |
| Class A | -0.1% | -1.3% | -0.9% | -0.1% | -9.1% | -9.8% | -0.1% | -9.1% | -10.3% |
| Class B | 0.0% | -1.9% | -1.3% | 0.0% | -1.9% | -1.3% | 0.1% | -1.9% | -1.5% |
| Class C | 0.0% | -1.2% | -1.6% | 0.0% | -1.2% | -1.6% | 0.1% | -1.2% | -1.6% |
| Class D | 0.1% | -0.8% | -0.9% | 0.1% | -0.8% | -0.9% | 0.1% | -1.0% | -1.1% |
| Class E | -0.1% | -1.0% | -1.0% | -0.1% | -1.0% | -1.0% | 0.0% | -1.1% | -1.3% |
| Class F | 0.1% | -1.5% | -1.9% | 0.1% | -1.5% | -1.9% | 0.1% | -1.5% | -2.2% |
| **Overall** | 0.0% | -1.3% | -1.2% | 0.0% | -2.6% | -2.8% | 0.0% | -2.7% | -3.0% |
|  | 0.0% | -1.3% | -1.2% | 0.0% | -2.6% | -2.7% | 0.0% | -2.6% | -2.9% |
| Enc Time[%] | 100% | | | 100% | | | 100% | | |
| Dec Time[%] | 99% | | | 99% | | | 98% | | |

Table 5 : Evaluation of decimation on JCTVC-G358

# Patent rights declaration(s)

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