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| *Title:* | **Non-RCE2: On sample adaptive intra prediction for oblique modes in lossy coding** | | |
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| *Author(s) or Contact(s):* | Ankur Saxena, Haoming Chen and  Felix Fernandes | Email: Tel: | [asaxena@sta.samsung.com](mailto:asaxena@sta.samsung.com),  [haoming.c@sta.samsung.com](mailto:haoming.c@sta.samsung.com),  [ffernandes@sta.samsung.com](mailto:ffernandes@sta.samsung.com)  1-972-761-7761 |
| *Source:* | Samsung Electronics, Co., Ltd. | | |

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# Abstract

Sample-based angular intra prediction (SAP) for lossless intra modes was presented in JCTVC-G093. In JCTVC-M0056, SAP for only the horizontal and vertical intra prediction modes was adopted in the HEVC Range Extensions version 3 for lossless setting, as operations for the horizontal and vertical modes can be fully parallelized at both the encoder and decoder. In JCTVC-M0351, SAP was proposed for lossy setting for horizontal, vertical and near-horizontal, and near-vertical modes. In this contribution, SAP for lossy scenario for oblique modes, such as strictly diagonal modes is presented. For these modes, SAP can also be fully parallelized at both the encoder and decoder. Applying SAP on these modes, in conjunction with applying SAP to horizontal and vertical modes in JCTVC-N0052 leads to upto 6.1%, 3.6% and 2.4% BD-Rate savings for all-Intra, random access and low delay configurations, respectively, for RGB 4:4:4 screen content sequences. For YUV 4:4:4 sequences, the respective gains are up to 5.1%, 3.2% and 1.6%.

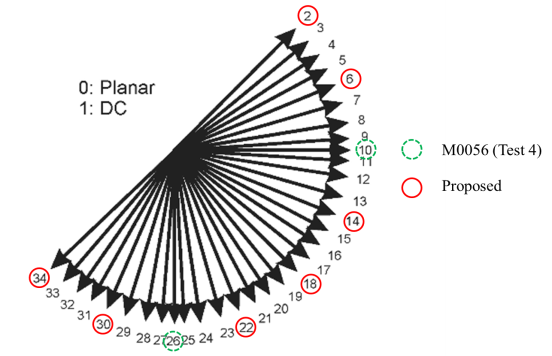
# Introduction

In sample-based adaptive intra prediction (SAP) [1, 2], the predictor for a sample (pixel) is a copy of neighboring sample, or a linear combination of adjacent samples. In the previous April 2013 JCTVC meeting, various tests on SAP were performed, and test 4 from [2] was adopted in the HEVC Range extensions software HM10.1+RExt3.0, and Range extensions working draft [3]. In JCTVC-M0351 [5], SAP was proposed for lossy setting for horizontal, vertical and near-horizontal, and near-vertical modes.

It was asserted in [2] that applying SAP on non-horizontal and non-vertical “oblique” modes is not fully parallel at the decoder side. While this is true in general for all the oblique modes, SAP for 3 strictly diagonal modes can trivially be parallelized at the decoder. Further, in JCTVC-N0176 [6], a parallel-version of SAP for other oblique modes with a novel prediction scheme, which can overcome the parallelism bottle-neck, and can achieve coding gains for screen content coding video sequences was presented. In this contribution, we extend the parallel-version of SAP for oblique modes in the lossy scenario.

# Extension of SAP on 7 angular modes

In Test 4 of JCTVC-M0056 [4], the unified angular prediction (UAP) for the vertical mode 26 and horizontal mode 10 (see Fig. 1) in HEVC was replaced with SAP, as indicated by green dashed circles. In our proposed scheme, we add more SAP modes: 2, 6, 14, 18, 22, 30 and 34, as shown by the red circle in Fig. 1.



**Figure 1. Replacement of unified angular prediction with SAP. In our scheme, we propose new prediction method for modes 2, 6, 14, 18, 22, 30 and 34.**

## SAP for Oblique Modes

The prediction method is shown in Fig. 2 (strictly diagonal modes: 2, 18 and 34) and Fig. 3 (other 4 modes: 6, 14, 22 and 30).

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|  |  |  |
| (a) | (b) | (b) |
| **Figure 2. Illustration of proposed SAP for three diagonal modes (2, 18 and 34) on 4×4 PU. The green shaded samples are reference samples. The orange colored samples get the prediction as the standard HEVC intra prediction. The white samples get the prediction from the integer pixel location from its bottom-left (respectively top-left, top-right) samples for mode 2 (respectively modes 18 and 34).** | | |

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
| (a) | (b) | (c) | (d) |
| **Figure 3. Illustration of proposed SAP for the four other angular modes (6, 14, 22 and 30). Similar to Fig. 2, the orange colored samples derive the prediction following the standard HEVC intra prediction. The prediction of the white samples comes along the arrow direction**. | | | |

For a block of size *M* (rows) ×*N* (cols), suppose the original pixel value is *p*(*i*,*j*) (), the derivation of the predictor is presented next.

## SAP for Oblique Modes(Lossy Setting)

SAP for lossy setting for horizontal and vertical modes was presented in [5]. For the lossy setting, SAP for oblique modes is performed in the following fashion:

1. Assume that after the prediction for a pixel p (i,j), the residue is r(i,j).
2. Let the transform be skipped, and let the quantized residue be given by Q (r(i,j)), where Q denotes the quantization operation.
3. Then SAP for lossy setting for oblique modes is performed as:

**Table 1: Step 3.a of prediction scheme for SAP for lossy oblique modes**

|  |  |
| --- | --- |
| Mode | Step 3.a of the Prediction Scheme at the encoder |
| 2 |  |
| 18 |  |
| 34 |  |
| 6 |  |
| 14 |  |
| 22 |  |
| 30 |  |

The modified residual sample  is quantized to produce. Then,  is calculated as:

**Table 2: Step 3.b of prediction scheme for SAP for lossy oblique modes**

|  |  |
| --- | --- |
| Mode | Step 3.b of the Prediction Scheme at the encoder |
| 2 |  |
| 18 |  |
| 34 |  |
| 6 |  |
| 14 |  |
| 22 |  |
| 30 |  |

The quantized modified residual samples  are then sent to the decoder. On the decoder side, the above calculations are repeated to produce. The quantized residuals are added to the original prediction values to produce reconstructed sample values.

**Comment:** For all the other oblique modes from 2 to 32, the extension to lossy setting from lossless SAP can be performed in a straightforward fashion as shown for modes 2, 18, 34, 6, 14, 22, and 30 above.

# Experimental results

In this section, coding results for SAP for oblique modes are presented according to the test conditions stipulated in RCE2 core experiment description [4] for lossy conditions. The anchor is HM 10.1-RExt-3.0 in lossless setting. Table 3 presents the coding efficiency with SAP on three diagonal modes 2, 18 and 32 in conjunction with SAP for horizontal and vertical modes in lossy setting [5]. The scheme is applied on blocks of size 4x4 only. Detailed results are in attached excel files.

**Table 3: Simulation results for proposed SAP for strictly diagonal, horizontal and vertical modes. Anchor is HM10.1-RExt-3.0.**



There was a bug in the above implementation, and the correct results are in Table 3.1 inline below:

**Table 3.1: Simulation results for proposed SAP for strictly diagonal, horizontal and vertical modes. Anchor is HM10.1-RExt-3.0 (with BugFix, in GBR order)**



# Throughput and complexity

## Throughput

Implementing SAP on all the oblique modes in parallel is necessary for hardware implementation, especially for the smaller blocks such as 4x4. On the decoder side, there are two parts: 1) samples along the boundary that follow the standard unified angular intra prediction; and 2) samples that follow the proposed sample-based adaptive prediction. For (1), it can be done in parallel as in the HEVC standard, since the prediction for all the pixels is readily available. Similarly, for (2), we know all the residual “integer” pixel values, and summing up the residuals can be easily implemented the decoder in parallel, similar with the Horizontal and Vertical SAP mode. Note that in our proposed scheme, we do not try to interpolate the (reconstructed) pixels in the middle rows as was presented in [4], and hence did not allow for parallel decoding.

## Complexity

In the encoder side, there is negligible additional complexity. In the decoder side, the additional complexity comes from the sum up of the residuals. For 4×4 and 8×8 blocks, to decode in parallel, the additional complexity is summarized in Table 4.

**Table 4: Addition Complexity for Parallel Decoding**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 4×4 | | 8×8 | |
|  | Additional Complexity | Addition/Sample | Additional Complexity | Addition/Sample |
| Modes 2, 18, and 34 | 14 additions | 0.875 | 140 additions | 2.1875 |
| Modes 6, 14, 22 and 30 | 6 additions | 0.375 | 84 additions | 1.3125 |
| H+V modes [2] in HEVC-Range Extensions | 24 additions | 1.5 | 224 additions | 3.5 |

# Conclusion

The proposed scheme achieves up to 6.1%, and 5.1% BD-Rate savings for screen content RGB 444 video, YUV444 video respectively in All Intra setting, and keeps the decoder fully parallel. We recommend to adopt this proposal in committee draft of HEVC range extensions.

# References

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# Patent rights declaration(s)

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