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| *Title:* | **On sample adaptive intra prediction for oblique modes in lossless coding** | | |
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| *Purpose:* | Proposal | | |
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# Abstract

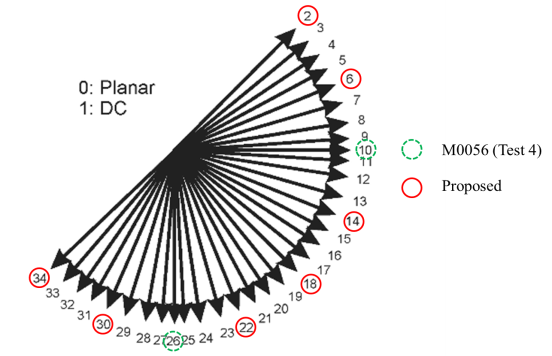
Sample-based angular intra prediction (SAP) for lossless intra modes was presented in JCTVC-G093. In JCTVC-M0056, SAP for only the horizontal and vertical intra prediction modes was adopted in the HEVC Range Extensions version 3, as operations for the horizontal and vertical modes can be fully parallelized at both the encoder and decoder. In this contribution, seven more SAP angular modes (HOR+8, VER±8, VER±4 and HOR±4) are proposed for lossless coding, and it is shown that these modes can also be fully parallelized at both the encoder and decoder. Applying SAP on these seven modes leads to average BD-Rate savings of 2.1% for All Intra, 1.5% for Random Access, and 1.4% for Low Delay-B settings for RGB444 screen content coding sequences, and 1.8% for All Intra, 1.2% for Random Access, and 1.3% for Low Delay settings for YUV444 screen content coding sequences.

# 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]. 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 this contribution, we propose a parallel-version of SAP for 4 more angular modes with a novel prediction scheme, which can overcome the parallelism bottle-neck, and can achieve coding gains for screen content coding video sequences.

# 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).** | | |

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| --- | --- | --- | --- |
|  |  |  |  |
| (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 prediction *pred* (*i*,*j*) is summarized in Table 1, where UAP denote the Unified Angular Prediction in HEVC standard (note that for square blocks in HEVC, M=N).

**Table 1:** Derivation of predictor for proposed oblique SAP modes

|  |  |
| --- | --- |
| Mode | Prediction Scheme |
| 2 |  |
| 18 |  |
| 34 |  |
| 6 |  |
| 14 |  |
| 22 |  |
| 30 |  |

# 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 lossless conditions. The anchor is HM 10.1-RExt-3.0 in lossless setting. Table 2 presents the coding efficiency with SAP on three diagonal modes 2, 18 and 32. Table 3 presents the coding efficiency with SAP on all seven modes. Detailed results are in attached excel files.

For tables 2 and 3, encoding and decoding times are not accurate. For tables 4 to 7, the encoding/decoding times are accurate.

**Table 2:** Simulation results (Proposed SAP applied on 3 diagonal modes. Anchor is HM10.1-RExt-3.0)



**Table 3:** Simulation results (SAP applied on 7 oblique modes. Anchor is HM10.1-RExt-3.0)



# Limitation of block size

In this section, we compare the performance by limiting SAP on different block sizes, which are up to 4×4, 8×8, 16×16 and 32×32 and 64×64(LCU). Tables 4, 5, 6 and 7 show the results. In Fig. 4, we show the characteristics on intra frame.

**Table 4:** SAP applied on only 4×4 blocks for 3 diagonal modes. Anchor is HM10.1-RExt-3.0



**Table 5:** SAP applied on 4×4 and 8×8 blocks for 3 diagonal modes vs. HM10.1-RExt-3.0



**Table 6: SAP applied on only 4×4 blocks for all 7 oblique modes. Anchor is HM10.1-RExt-3.0**



**Table 7: SAP applied on 4×4 and 8×8 blocks for all oblique 7 modes. Anchor is HM10.1-RExt-3.0**



|  |  |
| --- | --- |
|  |  |
| (a) | (b) |

Figure 4. Applying (a) only three diagonal modes (b) all seven modes on limited block sizes, which are up to 4, 8, 16, 32 and 64. Negative number means bitrate saving.

# 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 8.

**Table 8:** Additional 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 2.1% bitrate for the screen content video and keeps the decoder fully parallel. Based on the size limitation analysis, applying these methods on only 4×4 and 8×8 block sizes can achieve most of the coding gains. We therefore recommend to adopt this proposal in committee draft of HEVC range extensions.

# References

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3. D. Flynn, J. Sole, and T. Suzuki, “HEVC range extensions draft 3”, JCTVC-M1005, Incheon, Korea, April 2013.
4. R. Joshi, P. Amon, R. Cohen, S. Lee and M. Naccari, “HEVC Range Extensions Core Experiment 2 (RCE2): Prediction and coding techniques for transform-skip and transform-bypass blocks,” JCTVC-M1122, Incheon, Korea, April 2013.

# Patent rights declaration(s)

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