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| *Title:* | **CE6.b1 Report on Short Distance Intra Prediction Method** | | |
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# Abstract

This document reports the experimental results of the short distance intra prediction (SDIP) scheme for core Experiment 6 on intra prediction improvement. SDIP was presented in JCTVC-C101 and JCTVC-C270. By dividing the NxN block into lines or non-square blocks, SDIP can reduce the energy of the prediction residuals by reducing the distance of predicted pixel and its reference pixels. When integrated into the HM2.0 software, it was reportedly shows 2.5% and 4.0% bit rate saving on average, under all intra high efficiency and low complexity conditions, respectively, with about 24% (intra) and 47% (intra loco) encoding time increase and no obviously decoding time increase. Up to 6.4% bit rate saving is achieved on sequences with rich textures.

# Introduction

The traditional block-based intra coding in AVC/KTA/HM uses one NxN square block as the reconstruction unit and prediction unit. The pixels inside a square block are all predicted from the boundaries of neighboring reconstructed blocks, producing poor predictions for pixels on the right-bottom part than the others in some regions of sequences. To better exploit spatial correlations, the short distance intra prediction coding scheme is proposed by partitioning one NxN square block into several lines or non-square blocks with rectangle shape. In the block, pixels are predicted and reconstructed line by line or rectangle by rectangle. Therefore, the prediction distance can be obviously shortened.

# Algorithm description

In SDIP, one NxN square block which is smaller than 32x32 is divided into several lines or non-square blocks with rectangle shape. In the block, pixels are predicted and reconstructed line by line or rectangle by rectangle.

## Block Partitions

In SDIP modes, one CU that smaller than 64x64 can be partitioned as lines or non-square blocks with rectangle shape as Fig.1 shows. One 32x32 CU can be partitioned as four 8x32 or 32x8 Pus, and the 16x16 CU can not only be divided into four 8x8 PU as did in HM, but also be divided into four 4x16/16x4 PU, and a 4x16/16x4 PU can be further split into four 1x16/16x1 partitions. As similar, one 8x8 CU can also be divided into four 2x8/8x2 PU, and every 4x4 PU can be further divided into four 1x4/4x1 partitions. Hence, two types of PU are supported in SDIP, the first is rectangular PU named as hNx2N/2NxhN, where h means half (1/2), the second is line based PU named as 1xN/Nx1. For 32x32 CU, only rectangular SDIP PU is used. For 16x16 and 8x8 CU, both the rectangular and line based PU are supported because there are more textures in these kind of CUs.

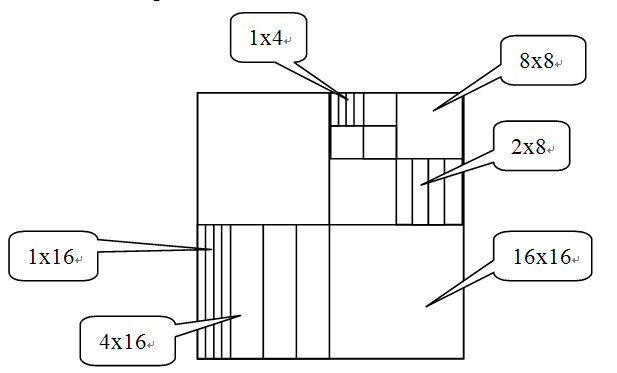


Fig. 1 SDIP block partitions based on HM

## SDIP intra prediction and coding



Fig.2 UDI prediction for 2x8

The prediction, transform and entropy modules in HM2.0 can be reused for SDIP partitions. In the prediction for SDIP partitions, UDI of HM is used as Fig.2 and the UDI modes can be from 9 to 34 and the number of modes is configurable as HM. One UDI mode flag is identified for every 4x16/16x4 or 2x8/8x2 partition. If a 4x16/16x4 is divided into four 1x16/16x1, the 1x16/16x1 partitions used the same modes that identified in 4x16/16x4 and similar for 1x4/4x1 partitions in 4x4 PU. In the prediction of SDIP blocks and square blocks, we used the bidirectional intra prediction for mode 6 (BUDI) as described in JCTVC-Exxx [1].

In the SDIP modes, chroma block was traditionally square block based coded, all four luma prediction modes in the current CU and the four modes 0-3 are tested in mode decision, among which the four luma modes are mapped to low indices and modes 0-3 are mapped to high ones. Only the first five modes by the new indices are searched in mode decision. The new index is then transmitted in the bitstream instead of the original modes. This approach is also applied to blocks not selecting SDIP mode, where SIZE\_NxN partitions might benefit from it.

The same transform matrices in HM2.0 were reused in SDIP modes but the transform size is partition size related and the quantization scale matrix is modified respectively. The *n*x*m* blocks are transformed by the following steps as described in [2].

**Cnxm = Tm x Bnxm x TnT** (1)

where **Bnxm** denotes a block with *n* pixels *m* rows. **Tn** and **Tm** are the transform matrices of size *n*x*n* and *m*x*m*, respectively. **Cnxm** denotes the transformed *n*x*m* block.

At the entropy coding stage, different scanning orders and contexts are designed for different partitions. Generally, for rectangular partitions, the coefficients are first scanned from high frequency to low frequency into a 1D buffer as did in MDCS of HM2.0, and then reorganized into a 4x4 or 8x8 block and coded as traditional. For 1x16 partitions, since the transform is one dimensional, there is no need to scan from high to low. The coefficients are directly reorganized into 4x4 and coded. For 4x4 using 1x4 transforms, the coefficients of a 4x4 block are coded as a whole. They are scanned from four DC coefficients to other AC coefficients. The significant map is coded using the frequency as a context, i.e. there are four context models for 4x4. The coefficient levels are coded similar to 4x4 in HM. In SDIP modes, RDOQ is used in both CABAC and LCEC.

# Test conditions and Results

The proposal has been integrated into HM2.0. Early skip method was used to reduce the encoding complexity, in which the intra mode was skipped when the RD costs are smaller than a threshold value. In addition, fast mode search method as like fast mode selection in HM2.0 was used. 5 modes are used for 1x4/4x1 and 8 modes for 2x8/8x2 and 3 modes for other partitions. The results were tested in Intra and Intra LoCo cases under the recommended test conditions of CE6. The following platform and compiler have been used and results were shown in Table1.

|  |  |  |  |
| --- | --- | --- | --- |
| **Platform** | **CPU** | **Memory** | **Compiler** |
| Windows Server 2003, 64 bits | Intel Xeon X7560 @2.27GHz | 256G RAM | VS2008 |

Table1. Results of normal configuration

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -1.0 | -0.5 | -0.8 | -2.1 | -2.0 | -2.6 |
| Class B | -1.9 | -1.0 | -1.4 | -3.7 | -3.7 | -4.8 |
| Class C | -3.5 | -2.4 | -2.6 | -4.8 | -5.0 | -5.7 |
| Class D | -3.6 | -2.1 | -2.2 | -5.1 | -4.8 | -5.2 |
| Class E | -2.9 | -2.2 | -2.1 | -4.9 | -7.5 | -6.0 |
| All | -2.5 | -1.6 | -1.8 | -4.0 | -4.4 | -4.8 |
| Enc Time[%] | 124% | | | 147% | | |
| Dec Time[%] | 103% | | | 104% | | |

The test results show that 2.5% and 4.0% bit rate saving on average, under all intra high efficiency and low complexity conditions, respectively. Up to 6.4% bit rate saving is achieved on sequences with rich textures.

**Additional results: 1x4\_OFF configuration**

The purpose of this configuration is to test the performance of SDIP while turning off the 1x4/4x1 mode for 4x4 PU. Table2 show the results of this configuration.

Table 2. Results of 1x4\_OFF configuration

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -1.1 | -0.6 | -0.9 | -2.0 | -2.0 | -2.6 |
| Class B | -1.9 | -1.1 | -1.5 | -3.6 | -3.8 | -4.9 |
| Class C | -3.2 | -2.4 | -2.6 | -4.1 | -5.0 | -5.7 |
| Class D | -3.2 | -2.1 | -2.2 | -4.2 | -4.7 | -5.0 |
| Class E | -3.0 | -2.4 | -2.2 | -4.8 | -7.5 | -6.1 |
| All | -2.4 | -1.6 | -1.8 | -3.7 | -4.4 | -4.8 |
| Enc Time[%] | 116% | | | 133% | | |
| Dec Time[%] | 101% | | | 101% | | |

The test results show that 2.4% and 3.7% bit rate saving on average, under all intra high efficiency and low complexity conditions, respectively. Up to 6.2% bit rate saving is achieved on sequences with rich textures.

**Additional results: 1x4\_OFF\_BUDI\_OFF configuration**

The purpose of this configuration is to test the performance of SDIP while turning off the 1x4/4x1 mode for 4x4 PU and turning off the BUDI for mode 6. Table3 show the results of this configuration. Compared with the BUDI only performance from [1], the results show that the gain of BUDI and SDIP was directly added without complexity increase.

Table 3. Results of 1x4\_OFF\_BUDI\_OFF configuration

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -0.7 | -0.5 | -0.8 | -1.4 | -1.7 | -2.4 |
| Class B | -1.5 | -0.9 | -1.4 | -3.2 | -3.4 | -4.5 |
| Class C | -2.8 | -2.3 | -2.5 | -3.7 | -4.6 | -5.3 |
| Class D | -2.9 | -2.0 | -2.1 | -3.8 | -4.4 | -4.7 |
| Class E | -2.6 | -2.3 | -2.3 | -4.4 | -7.4 | -5.9 |
| All | -2.0 | -1.5 | -1.8 | -3.2 | -4.1 | -4.5 |
| Enc Time[%] | 116% | | | 133% | | |
| Dec Time[%] | 101% | | | 99% | | |

Table 4. Results of BUDI only from JCTVC-E286



**Additional results: 1x4\_OFF\_inter configuration**

The purpose of this configuration is to test the performance of SDIP for Random access and Low delay cases while turning off the 1x4/4x1 mode for 4x4 PU. Table 5 shows the results of this configuration that the SDIP can also achieve the considerable gain for RA and LD cases without obvious encoding or decoding time increase.

Table 5. Results of 1x4\_OFF for RA and LD cases

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Random access | | | Random access LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -0.6 | 0.0 | -0.3 | -1.2 | -0.3 | -0.7 |
| Class B | -1.1 | -0.7 | -1.4 | -2.2 | -1.7 | -2.2 |
| Class C | -1.7 | -1.5 | -1.5 | -2.1 | -1.9 | -2.1 |
| Class D | -1.5 | -1.6 | -1.3 | -1.9 | -1.8 | -2.2 |
| Class E |  |  |  |  |  |  |
| All | -1.2 | -0.9 | -1.1 | -1.9 | -1.4 | -1.8 |
| Enc Time[%] | 106% | | | 106% | | |
| Dec Time[%] | 100% | | | 100% | | |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Low delay | | | Low delay LoCo | | |
|  | Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A |  |  |  |  |  |  |
| Class B | -0.4 | -0.4 | -0.5 | -1.0 | -0.8 | -0.6 |
| Class C | -0.7 | -0.7 | -0.9 | -1.1 | -0.9 | -1.3 |
| Class D | -0.6 | -0.8 | -1.1 | -0.7 | -0.7 | -1.0 |
| Class E | -1.0 | -1.6 | 0.3 | -1.5 | -2.7 | -1.7 |
| All | -0.6 | -0.8 | -0.6 | -1.0 | -1.1 | -1.1 |
| Enc Time[%] | 105% | | | 104% | | |
| Dec Time[%] | 100% | | | 100% | | |

# Complexity Analysis

As can be observed in Table 1 and 2, the decoding times are kept consistent as HM2.0 anchor because the SDIP modes and current HM intra modes are exclusive on the decoder side and their operations are quite similar. The increasing of encoding time is mainly due to the RDO search for the best mode decision. The encoding time can be further reduced if some fast mode decision algorithms apply which also could give flexibilities for different applications.

SDIP uses the transform cores that have already existed in current HM software, which means no or minimum hardware overhead will be introduced by using SDIP technique. Future study or modification can also be easily implemented if new transform (CE10) is adopted.

Memory bandwidth is decided by the worst case memory access time. Two cases have been studied: In the first case, the smallest partitions of SDIP are 1x4 are 4x1 which means the smallest number required by SDIP operation is 4 pixels. The second case, the smallest number required is set to the same as block based intra coding, i.e. 16 pixels. 2x8, 8x2, 1x16, 16x1 are the smallest partitions in this case. Compared with the results of Table 1 and 2, the gain losses for case 2 are 0.1% for intra and 0.3% for intra loco. But the encoding time is reduced by 5% and 14% respectively.

# Conclusion

This document reports the experimental results of SDIP scheme for core Experiment 6 on intra prediction improvement. When integrated into the HM2.0 software, it shows 2.5% and 4.0% bit rate saving on average, under all intra high efficiency and low complexity conditions. Up to 6.4% bit rate saving is achieved on sequences with rich edges. Therefore, we recommend to adopt the SDIP into HM as an extension of traditional square NxN partitions, and to further improve the Intra coding efficiency of HEVC based on new version of HM.

# References

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# Patent rights declaration(s)

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