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| *Title:* | **Core Experiment 6: Intra Prediction Improvement** | |
| *Status:* | Output Document to JCT-VC | |
| *Purpose:* | CE Description | |
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# Abstract

This output document provides a list of key Core Experiment 6 (CE6) contributions on Intra Prediction Improvements.

# Introduction

Intra prediction improvement core experiments are divided into 7 categories

1. CE6.a: Block Based Intra Prediction
2. CE6.b: Short Distance Intra Prediction
3. CE6.c: Edge Based Intra Prediction
4. CE6.d: Parallel Intra Coding
5. CE6.e: Planar Intra Prediction
6. CE6.f: Intra Smoothing
7. CE6.g: Number of Intra Prediction Directions

# Experimental Conditions

## Software

CE will be implemented into the HM2.0 software that is recommended by the TM software group at the end of Deagu meeting.

## Test Sequences, Bit Rates and Coding Conditions

In this CE, the recommended Test conditions of Intra-only configuration and Test sequences as defined in the document JCTVC-D600 and provided in the reference config files by the TM software group will be used for all sub-CE tests. The participants could consider either Intra High Efficiency or Intra Low Complexity or both. In addition, the AIS flag needs to be set to “ON”. AIS related CEs can be done independently.

## Evaluation of CE Results

Results of the CE will be evaluated on the basis of BD-measures. In addition subjective evaluation to support the advantage of the proposed tools is highly desirable.

## Evaluation of Complexity

For the complexity measurement, the anchor, the reference software and the reference software with the tool implemented will be executed on the same machine and the computational time will be measured for each software. Then, a time factor is calculated which compares the reference software including the sub-CE test tool and the reference software without the tool.

# Timelines

|  |  |
| --- | --- |
| **February 11, 2011** | HM2.0 software available |
| **Daegu + 2Wks** | Deadline for sending email to coordinator expressing interest participating in core experiment. |
| **March 06, 2011** | Cross-verification completed CE. |
| **March 11, 2011** | Report the verification results uploading |

# Description of Tool Experiment

## CE6.a: Block Based Intra Prediction

### JCTVC-D108: Bidirectional Intra Prediction (Toshiba)

Bidirectional Intra Prediction (BIP) is a spatial prediction method for intra coding and mainly consists of two schemes, the weighted bidirectional prediction (WBP) and the implicit BIP mode derivation (IBMD). WBP combines two unidirectional intra predictions results by a weighted sum according to the distance between the predicted pixel and the reference pixel(s) used for prediction. These unidirectional intra predictions are based on Unified Intra Prediction (UIP) integrated in current TMuC/HM software. The sample in the bidirectional prediction at pixel position (n), predBi[n], is derived from the following equation:

predBi[n] = ( w[n] \* xL0+ ((1<<w\_shift) - w[n]) \* xL1 + (1<<(w\_shift-1))) >> (w\_shift)

where xL0 and xL1 are the samples of either unidirectional predictions or reference pixels, and w[n] is the weighting list for xL0 according to the sample position (n). w\_shift shows the precision of the weighting list. The weighting list w[n] is pre-determined according to the difference of distance between two prediction directions.

IBMD is a kind of direct mode derivation and derives the two prediction directions of current PU using prediction directions kept at one or two available neighboring PU(s). An example of this implicit derivation using left PU A and above PU B is shown in Figure 1.



**Figure 1: An example of implicit BIP mode derivation**

By combining two unidirectional predictions with weighted averaging, it is expected to predict multi-directional texture and reduce the coding noise of the reference pixels. Moreover, by introducing IBMD, the overhead of BIP mode can be reduced significantly.

The followings items will be investigated in this CE in order to follow the recommendation by JCTVC-D443 and the committee: (1) To study complexity reduction, (2) To study on harmonization with a similar bidirectional intra prediction method proposed in JCTVC-D300 as a single proposal, (3) To study on potential combinations with BIP and the other intra prediction methods, and (4) To investigate on the interaction between intra prediction and spatial transform.

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### JCTVC-D287 : Bi-Intra Prediction using slope information

#### Bi-Intra Prediction (BIP)

The proposed BIP [1] uses the concept of slope to increase the performance of UIP [2]. For all direction modes used in UIP except for DC mode, the difference between two neighboring parts of the current block is calculated. One neighboring part is next to the reference line and other is next to the last horizontal (or vertical) line of the current block according to the prediction direction. In case of vertical prediction directions, the difference is calculated between two left neighboring parts of the last horizontal line and the corresponding reference line. For horizontal prediction directions, upper-extended parts of the last vertical line and the corresponding vertical reference line are used to calculate the difference. The averaged difference between them is offset which provides the information for slope. The slope is not encoded since the decoder can calculate it.

After offsets are calculated, the last line of the current block is predicted by adding the offset to the precition values provided by UIP. And then, the other lines of the current block are predicted by bi-linear interpolation with the neighboring pixels and the prediction values of the last line. It may be noted that the size of the neighbor lines used to calculate offset is half of that of the current block.

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#### Reference

[1] “Bi-Intra Prediction using slope information”, JCTVC-D287: Daegu, January 2011.

[2] “WD1: Working Draft 1 of High-Efficiency Video Coding,” JCTVC-C403, 3rd JCT-VC Meeting, Guangzhou, CN, Jul 2010

### JCTVC-D300: Bidirectional intra prediction for positive directions in UDI (HiSilicon)

This document describes an Intra prediction for positive directions in UDI which was proposed in JCTVC-D300. In the proposed *method, both the reference pixels from main and side arrays can be further exploited to improve prediction accuracy*. The prediction value of a particular point is linearly interpolated from the two reference points. UDI Intra prediction uses main and side arrays as prediction references. When Intra prediction direction is positive, the reference pixels from the main array are used for prediction.

The pixel P(*x*, *y*) in current block has two corresponding reference pixels from main and side arrays, where *ref*1 denotes the reference pixel from main array, and *ref*2 denotes the other reference pixel from side array. The prediction value of P is calculated by using equation (1) through a linear interpolation method.

P’(*x*, *y*) = (*ref*1\**d*2 + *ref*2\**d*1)/(*d*1+*d*2) (1)

Where, P’ is the prediction value of the pixel P, *d*1 and *d*2 are spatial distances from P to *ref*1 and *ref*2 pixels, respectively.

The followings items will be investigated in this CE in order to follow the recommendation by JCTVC-D443 and the committee: (1) To study complexity reduction and extension of the method to other positive intra modes. (2) To study on harmonization with a similar bidirectional intra prediction method proposed in JCTVC-D108 as a single proposal, (3) To study on potential combinations with BIP and the other intra prediction methods, and (4) To investigate on the interaction between intra prediction and spatial transform.

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### JCTVC-D350: Chroma intra prediction by reconstructed luma samples

In the proposed method, chroma samples are predicted from reconstructed luma samples of the same block by a linear model. The chroma values are predicted from reconstructed luma values of the same block as follows.



whereindicates the prediction of chroma samples in a block and indicates the reconstructed luma samples in the block. Parameters  and are derived from causal reconstructed samples around the current block.

In the proposed method, the look-up table and multiplication is used to replace division when calculating parameter. All operation is implemented with integer implementation within 32 bits data accuracy. The detailed implementation of LM prediction method can found in JCTVC-D360.

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## CE6.b: Short Distance Intra Prediction

### CE6.b1: Short Distance Intra Prediction Method

The purpose of this CE subset is to study the coding performance of intra prediction with minimum complexity and explore the combinations of short distance intra prediction method with other different approaches of intra prediction

#### JCTVC-D299, Short Distance Intra Prediction Method (Microsoft, Huawei, HiSilicon)

D299 proposed a short distance intra prediction (SDIP) method by partitioning one NxN square block into several lines or non-square blocks with rectangle shape. The purpose of this CE subset is to study the coding performance of intra prediction with minimum complexity and explore the combinations of SDIP with different approaches of intra prediction. Further reducing the encoding complexity and investigation of decoder complexity of SDIP will be also included.

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. In the Intra prediction for SDIP partitions, UDI of HM is used and the number of modes is configurable as HM. The same transform matrices (2x2, 4x4, 8x8 and 16x16) in HM were reused in SDIP modes but only the transform size is partition size related and the quantization scale matrix is modified respectively. At the entropy coding stage, for 2x8, 1x16 and 4x16 partitions, the coefficients are first scanned into a 1D buffer and then reorganized into a 4x4 or 8x8 blocks and then entropy coded.

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### CE6.b2: Combined Intra Prediction

Combined intra prediction comprises a weighted combination of an angular (closed-loop) prediction together with a local mean prediction (open-loop prediction, OLP). The local mean is constructed as the average of the selected neighboring pixel values. The selected values are defined by an OLP template. In the example from Figure 2, the OLP template consists of three pixels - the left, top-left and above the current pixel.

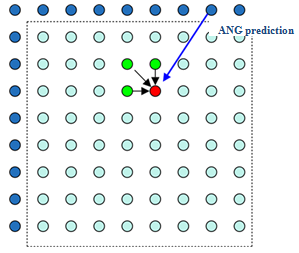


Figure 2: Example of Combined Intra Prediction utilizing a local mean and ANG prediction

CIP was a part of BBC's response to the Call for Proposals [1]. In a later contribution [2] using TMuC 0.9 it is reported that CIP can contribute to the BD-rate gains in intra HE and LC configurations. Moreover, in [2] additional properties of CIP have been presented, enabling selection of CIP settings of different complexities and parallelizable processing capabilities.

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#### Reference

[1] JCTVC-A125: BBC's Response to the Call for Proposals on Video Compression Technology

[2] JCTVC-D191: CE6: Report and evaluation of new Combined Intra Prediction setting

## CE6.c: Edge based Intra Prediction

### JCTVC-D279 (Sony, Sharp, Panasonic)

DCIM (Differential Coding of Intra Modes) is a method categorized as so-called Edge based Intra Prediction, which has been evaluated in CE [1]. The latest DCIM results are summarized in D279 [2], and the relevant algorithm descriptions and performance reports can be found in [3-6]. In this CE, the performance of DCIM integrated into the latest HM reference software will be evaluated. In addition, the combination/harmonization of DCIM and other intra coding tools will be tested.

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#### Reference

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[2] “CE6.c: Summary and Improvements of DCIM”, JCTVC-D279, Daegu, January 2011.

[3] “Video coding technology proposal by France Telecom, NTT, NTT DoCoMo, Panasonic and Technicolor”, JCTVC-A114, Dresden, April 2010.

[4] “Differential Coding of Intra Modes (DCIM)”, JCTVC-B109, Geneva, July 2011.

[5] “TE6.b: Experiment results of DCIM”, JCTVC-C169: Guangzhou, October 2010.

[6] “Analysis and improvement of differential coding of intra modes”, JCTVC-C176, Guangzhou, October 2010.

[7] “Evaluation of Most Probable Mode”, JCTVC-D112, Daegu, January 2011.

[8] “CE6.c: Experimental results of DCIM”, JCTVC-D389: Daegu, January 2011.

## CE6.d: Parallel Intra Coding

In contribution (JCTVC-D074), the concept of parallel intra-prediction unit (PPU) is introduced. The PPU defines the size of a block that can be coded using parallelization. The motivation for the PPU is not to increase complexity any further– the serial bottleneck in intra-prediction is not determined by simply the number of blocks within an LCU, but also by the size of the blocks that are being intra-coded. For blocks larger than a defined PPU size, a normal sequential prediction is performed. For blocks falling within a PPU, if they are further partitioned, parallel intra prediction may be employed. Such a block is referred as a Parallel Prediction Block (PPB). The size of a PPB is equal or less than the size of a PPU.

In this contribution, there are two cases where parallel intra may be applied. In the first case, the PPU is split into 4-8x8 blocks, and at least one of these blocks is further divided into 4x4 blocks. Blocks that are further divided into 4x4 blocks are each a PPB in this solution, as shown in Fig. 3(a). In the second case, a 16x16 PPU is split entirely into 4x4 subblocks and is an entire PPB, as shown in Fig. 3(b). For additional information on the prediction process, JCTVC-D074 can be used as the reference.

(a) (b)

**Figure 3: Illustration of Parallel Prediction Block**

### Participants

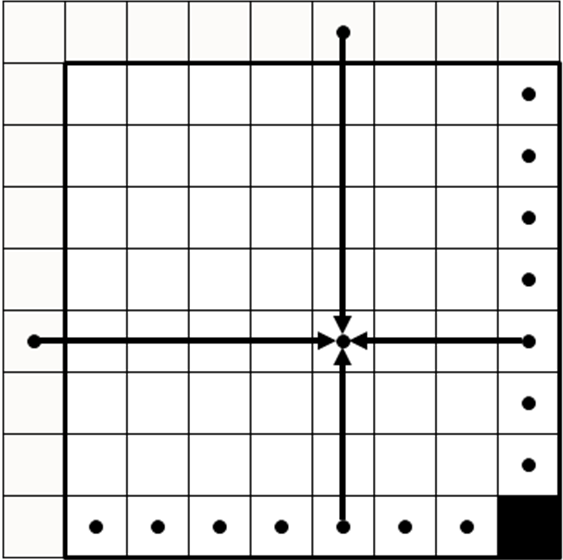
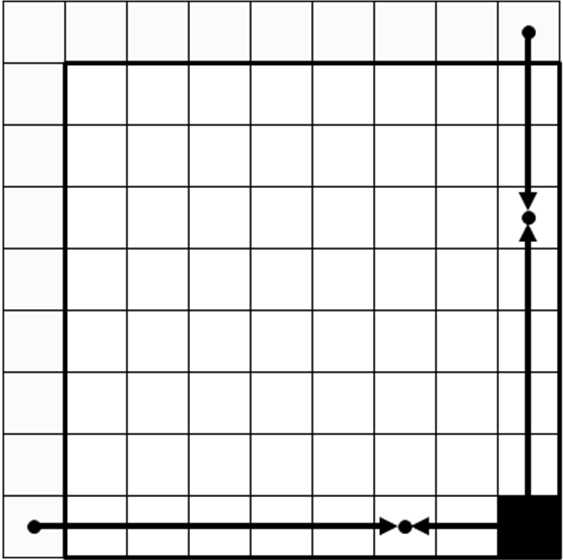
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## CE6.e: Planar Intra Prediction

Planar prediction methods have been proposed in a number of Daegu meeting contributions (e.g. by Nokia, LG, NTT-DOCOMO, NEC, etc.). The aim of this core experiment is to measure performance of different configurations and combinations of the proposed planar intra prediction methods.

### Planar Intra Prediction (JCTVC-D326 / Nokia, JCTVC-D083 / LG, JCTVC-D235 / NTT DOCOMO, JCTVC-D026 / Santa Clara University)

Planar Prediction is used to predict and reconstruct smooth regions. The common idea in different approaches is to provide a spatial prediction which is continuous along the block boundaries. Figure 4 below illustrates the sample reconstruction process for one of the Planar approaches.



**Figure 4: Reconstruction process for a block coded in Planar mode as described in JCTVC-D326. Border samples are obtained by linear interpolation, while the middle samples are obtained by bilinear interpolation from the border samples.**

The following configurations of the different approaches will be tested in this core experiment.

1. Substitute DC prediction with different planar prediction alternatives:
   1. Planar prediction as defined in JCTVC-D326, disabling the adjustment for corner sample (bilinear prediction of samples)
   2. Planar prediction as defined in JCTVC-D083 (bilinear prediction of samples followed by a refinement step)
   3. Planar prediction as defined in JCTVC-D235 (averaging two linear interpolations)
   4. Plane prediction as defined in JCTVC-D026 (TMuC plane mode)
   5. Planar prediction as defined in JCTVC-D326, disabling the adjustment for corner sample (averaging two linear interpolations)
   6. Planar prediction as defined in JCTVC-D083 (averaging two linear interpolations followed by a refinement step)
2. Test different prediction error coding approaches for the planar block:
   1. Default HM prediction error coding based on DCT
   2. DST based prediction error coding as in JCTVC-D235
   3. Indicating the corner sample explicitly as in JCTVC-D326 in addition to DCT coding
3. Different methods to indicate planar mode
   1. PU level indication substituting DC mode
   2. PU level signaling as an additional prediction mode
   3. CU level indication jointly for all color components (disabling prediction error coding)
   4. Utilizing both one of the planar modes and the plane mode as additional modes

As the number of possible combinations of different aspects is large, the proponent shall carry out initial tests and agree which of the combinations are to be reported, cross checked and evaluated subjectively.

Results to be reported are to follow the latest common testing condition for Intra configurations. In addition to the objective results proponents are to provide decoded sequences at the 5th JCT-VC meeting in Geneva for visual comparison. Participants including cross-checkers are also going to carry out subjective testing of selected tests of each proposal prior to the Geneva meeting on an agreed subset of sequences (Random Access configuration).

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## CE6.f: Intra Smoothing

### Introduction

The purpose of this category is to investigate the performance of intra smoothing related method(s). This test would address exploring the compression efficiency and complexity of proposed intra smoothing method(s) compared to the look-up table based adaptive intra smoothing method (Mode dependent Intra Smoothing or MDIS) going to be adopted into HM2.0.

### JCTVC-D109: “LUT-based Intra Prediction Filtering”, Mitsubishi

The LUT-based Intra Prediction scheme in JCTVC-D109 is applying filtering only on DC prediction samples, where only left and upper most pixel lines of the prediction samples are filtered using 2 tap filters, as shown in Figure 5, and no additional processing is applied on the rest of the prediction samples. The LUT for this scheme is also shown in Table 1. In the proposed scheme, adaptive intra smoothing proposed in JCTVC-C234 is also applied so that prediction samples except DC prediction mode can be smoothed with almost no complexity increase.



**Figure 5: Coefficients for LUT-based Intra Prediction Filtering**

Table 1: LUT for each PU size and intra prediction mode

|  |  |  |  |
| --- | --- | --- | --- |
| **PU Size** | **Filter mode** | | |
| **Filter #0** | **Filter #1** | **Filter #2** |
| 4x4 | - | - | mode 2 |
| 8x8 | - | mode 2 | - |
| 16x16 | mode 2 | - | - |
| 32x32 | - | - | - |
| 64x64 | - | - | - |

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### JCTVC-D282:”Mode dependent multi filter intra smoothing”, Qualcomm

In this proposal, a multiple intra smoothing method is proposed. Multiple filters are introduced and investigated in order to improve the performance of the current intra smoothing method in HM1.0. The filter selection is based on the intra prediction mode, prediction unit size, and/or pixel position without significant encoder/decoder complexity increasing.

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## CE6.g: Number of Intra Prediction Directions

### Introduction

An increased number of directions for intra prediction was introduced in the TMuC and will be integrated into the HEVC Test Model. During the 4th JCT-VC meeting in Daegu, Mode Dependent Intra Smoothing (MDIS) as well as an intra prediction mode decision method are decided to be adopted into HM2.0. Additionally, HM2.0 restricts the usage of NxN splitting except smallest CU size, which may also affects the intra prediction characteristics.

The vertical and horizontal intra prediction modes of 64x64 partition also needs to be verified, as it was not tested in the previous CE10 on number of intra prediction directions.

The purpose of this subcategory is to characterize the performance and complexity of using different numbers of intra prediction directions in conjunction with the newly adopted intra coding scheme in HM2.0. The characterization will be performed by investigating the coding efficiency improvement in terms of BD-BR performance, and by determining the complexity increase for both encoding and decoding using variety of combinations of intra prediction directions for each block size.

### Test points

The test points are identified in the table below with respect to the number of intra prediction directions up to the one defined for the HM default configurations. The test shall use HM2.0, which is expected to include all the changes agreed to be adopted into HM according to the results from the Daegu meeting.

**Table 2: Performance Tests for different combinations of number of intra prediction directions**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Block**  **size** | **Number of Intra Prediction Directions** | | | | | | |
| **Reference** | **Test** | | | | | |
| **#1** | **#2** | **#3** | **#4** | **#5** | **#6** |
| 4x4 | **17** | **17** | **17** | **17** | **17** | **17** | **17** |
| 8x8 | **34** | **34** | **17** | **34** | **34** | **34** | **34** |
| 16x16 | **34** | **34** | **34** | **17** | **34** | **34** | **34** |
| 32x32 | **34** | **34** | **34** | **34** | **17** | **9** | **34** |
| 64x64 | **3** | **3** | **3** | **3** | **3** | **3** | **1** |

**Table 3: Default configurations in TComRom.cpp file**

|  |  |
| --- | --- |
| **Default configurations** | #if UNIFIED\_DIRECTIONAL\_INTRA  const UChar g\_aucIntraModeNumAng[7] =  {  3, // 2x2  17, // 4x4  34, // 8x8  34, // 16x16  34, // 32x32  3, // 64x64  };  const UChar g\_aucIntraModeBitsAng[7] =  {  2, // 2x2  5, // 4x4  6, // 8x8  6, // 16x16  6, // 32x32  2, // 64x64  }; |

**Table 4: value for g\_aucIntraModeBitsAng**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Number of Directions | 3 | 5 | 9 | 17 | 34 |
| Number of bits | 2 | 3 | 4 | 5 | 6 |

#### Participants List

|  |  |  |
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