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| *Title:* | **Core Experiment 6: Intra Prediction Improvement** | |
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1 Introduction 2

2 Experimental Conditions 2

2.1 Software 2

2.2 Test Sequences, Bit Rates and Coding Conditions 2

2.3 Evaluation of CE Results 2

2.4 Evaluation of Complexity 2

3 Timelines 2

4 Description of Tool Experiment 2

4.1 CE6.a: Block Based Intra Prediction 2

4.1.1 JCTVC-C079: Bidirectional Intra Prediction (Toshiba) 2

4.1.2 JCTVC-C206: Chroma intra prediction from reconstructed luma samples (Samsung Electronics) 3

4.1.3 JCTVC-C193: Overlapped Block Intra Prediction (MediaTek) 4

4.1.4 JCTVC-C111: Optimizing the combination of current intra predictors (Santa Clara University) 5

4.2 CE6.b: Line/Pixel based Intra Prediction 6

4.2.1 Combination and Optimization of TE6.a.2 & TE6.a.4 (Microsoft, Huawei, Hilsillicon) 6

4.2.2 JCTVC-A125, JCTVC-C213: Combined Intra Prediction, (BBC, Sharp, NEC) 7

4.3 CE6.c: Edge based Intra Prediction 8

4.3.1 JCTVC-C169, JCTTVC-C176 (Sony, Sharp) 8

4.4 CE6.d: Parallel Intra Coding 9

4.4.1 JCTVC-B112 (Sharp Labs. of America) 9

5 Reference 11

# Introduction

The goal of this Core Experiment (CE) is to improve intra prediction in the HEVC Test model. We have divided the tests into four categories:

1. Block Based Intra Prediction
2. Line/Pixel Based Intra Prediction
3. Edge Based Intra Prediction
4. Parallel Intra Coding

# Experimental Conditions

## Software

CE will be implemented into the TMuC 0.9 software that is recommended by the TM software group at the end of this meeting in Guangzhou.

## 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 C500 [1] 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.

## 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

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| **November 1, 2010** | TMuC 0.9 software available |
| **Guangzhou + 2Wks** | Deadline for sending email to coordinator expressing interest participating in core experiment. |
| **January xx, 2011** | Cross-verification completed CE. |
| **January xx, 2011** | Report the verification results uploading |

# Description of Tool Experiment

## CE6.a: Block Based Intra Prediction

### JCTVC-C079: Bidirectional Intra Prediction (Toshiba)

Bidirectional Intra Prediction (BIP) is a spatial prediction scheme for intra coding. BIP 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 software. BIP has the unidirectional intra prediction modes (UIP modes) and bidirectional intra prediction modes (BIP modes), and one intra prediction mode is selected for each PU. Figure 1 shows the example of UIP and BIP modes.

Figure 1: UIP and BIP modes.

The sample in the bidirectional prediction at pixel position (n), predBi[n], is derived from the following equation:

predBi[n] = ( w[n] \* predL0[n] + ((1<<w\_shift) - w[n]) \* predL1[n] + (1<<(w\_shift-1))) >> (w\_shift)

where predL0[n] and predL1[n] are the samples in the two unidirectional prediction, and w[n] is the weighting list for predL0[n] 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.

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.

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### JCTVC-C206: Chroma intra prediction from reconstructed luma samples (Samsung Electronics)

The goal of proposed method is utilized cross-channel correlation to improved chroma intra prediction.

This method utilizes the linear relationship to modelize the correlation of luma signal and chroma signal. The chroma values are predicted from reconstructedd luma values of collocated block as follows.



where indicates 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.

Luma and chroma components have different sampling ratios in YUV420 sampling. The sampling ratio of chroma components is half of that of luma component and has 0.5 pixel phase difference in vertical direction. Reconstructed luma needs downsampling in vertical direction and subsample in horizontal direction to match size of chroma signal, as follows.



In this contribution, linear least square solution between causal reconstructed data of downsampled luma component and chroma component is used to derive model parameters  and .





Float point operation is involved in above equation to calculate parameters  to keep high data accuracy. And float point multiplication is involved in to calculate chroma prediction value when is represented by float point value. In this section, the integer implementation of this algorithm is designed. In the new method lookup table, multiplication and shift is used to replace division operation. Data is adaptively scaled to reduce the implementation cost and overflow of 32 bits data range representation.

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### JCTVC-C193: Overlapped Block Intra Prediction (MediaTek)

An intra prediction method, named as overlapped block intra prediction (OBIP), is described here (originally proposed as a part of JCTVC-A109). The idea of OBIP is similar to the well-know overlapped block motion compensation (OBMC) technique if we draw an analogy between the role of motion vectors in inter-prediction and the role of directional modes in intra-prediction. In this method, the final intra predictor (for a prediction block) is a weighting sum of three predictors formed by using the intra prediction modes of the current block, the left block, and the upper block, respectively. The weighting values are pixel position dependent and are obtained by offline training.



Figure 2: Illustration of neighboring blocks to the left and to the top of the current block

Detailed description about OBIP is as follows. As depicted in Figure 2, the neighboring blocks to the left and to the top of the current block are denoted as *A* and *B,* respectively. The intra-prediction modes for block *A*, *B*, and the current block are denoted as *ModeA*, *ModeB*, and *ModeC*, respectively. For a pixel *S*(*i*, *j*), where (*i*, *j*) is the coordinate in the current block, three possible predictors *PC*(*i*, *j*), *PA*(*i*, *j*), and *PB*(*i*, *j*) can be generated by the normal directional prediction method as in TMuC with *ModeC*, *ModeA* and *ModeB* respectively. Then the prediction *P*(*i*, *j*) for *S*(*i*, *j*) can be calculated as

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| --- | --- | --- |
|  |  | ( 1 ) |

where is the weighting value on *PX*(*i*, *j*) when the current block mode is *ModeC*. *ModeCQ* is obtained by quantizing *ModeC* from 34 or 17 values in TMuC to 9 values as in H.264/AVC. Thus, the prediction *P*(*i*, *j*) for *S*(*i*, *j*) is formulated as a weighting sum of three possible predictors *PC*(*i*, *j*), *PA*(*i*, *j*), and *PB*(*i*, *j*). The weighting values depend on the pixel positions (*i*, *j*), the quantized current block mode *ModeCQ*, and the position of the weighted predictor (X). The weighting values are offline trained and do not change throughout the encoding or decoding process.

In TMuC, there are three kinds of units: coding unit (CU), prediction unit (PU) and transform unit (TU). OBIP is performed at TU level in Intra CU when TU size is 4x4 or 8x8. We choose to use TU level is because that intra-coding TU can also be regarded as a prediction unit. When RQT is on, different TU levels can be adaptively chosen within one PU. If TU size if smaller than PU, the intra prediction will be performed at TU level. Therefore, one TU can choose whether to use OBIP or not according to RDO criterion and a switch flag must be coded and transmitted at TU level.

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### JCTVC-C111: Optimizing the combination of current intra predictors (Santa Clara University)

The purpose of this CE is to evaluate existing intra predictors in current TMuC software and find an optimal combination of these predictors along with the predictors in Unified Intra Prediction (UIP) with minimum complexity.

Besides the 34 predictors in UIP, 3 other predictors have been integrated in TMuC software, which are Planar, Plane and Bi-linear predictor. Current default configuration only switches on the Plannar predictor, but the reason is not clear. And the combination of Plane and Bi-linear predictor with UIP has not been investigated.

Some proposals of this meeting, e.g. C111 [2] (SCU & Hisilicon), C206[3](Samsung) and C263[4](Qualcomm) presented evidences that coding performance can be further improved by modifying the mapping table of intra prediction mode [4], or replacing down-right mode by Plane mode [3], or introducing Plane mode as another non-directional mode[2].

This CE will test different combinations of Plannar, Plane and Bi-linear predictor with UIP predictors, and evaluate the corresponding complexity. The method of deriving intra prediction mode for the current PU will also be evaluated.

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## CE6.b: Line/Pixel based Intra Prediction

### Combination and Optimization of TE6.a.2 & TE6.a.4 (Microsoft, Huawei, Hilsillicon)

The purpose of this CE subset is to improve the coding performance of intra prediction with minimum additional complexity in the HEVC test model by using the correlation between lines and pixels as proposed in JCTVC-C101and JCTVC-C270.

To better exploit spatial correlations, the line and pixel based intra coding scheme is proposed. In a block, pixels are predicted by its neighboring line or pixels. Therefore, the prediction distance is largely shortened.

The step of exploring the correlations between lines consists of line-based modes which can be 1x16, 16x1, 2x8 and 8x2. There are multiple directional predictions for each mode by shifting up or down or left or right of its neighboring reference line. The prediction with minimum RD cost is selected as the final prediction direction for each mode. DCT and scan with respect to the corresponding size of each mode are applied after the prediction. In the step of exploring the correlation among the pixels, a coding unit is decomposed into 4 blocks by down-sampling. One of the down-sampled blocks can be further decomposed into 4 sub-blocks. For each resample-based partition, the bottom-right decomposed block is firstly encoded with conventional block-based intra prediction. Then the other adjacent blocks on the top and left are predicted pixel-by-pixel from the first reconstructed block by horizontal and vertical interpolation respectively. JCTVC-C101

In the adaptive line-based intra coding scheme, each line of a block is coded and reconstructed as a basic unit. The line can be a row or a column. In the row-by-row coding, the first row of the current block is coded and then reconstructed. The reconstructed of the 1st row can be used to predict the second row. The process goes until all rows of the current block are coded. The column-by-column coding is similar. For each line, the surrounding reconstructed pixels are used to predict the pixels. After the prediction, a 1-D DCT is applied to the residue or the residue can be directly quantized without a transform. Besides, content-adaptive prediction filters are utilized to fully exploit correlations among lines. JCTVC-C270

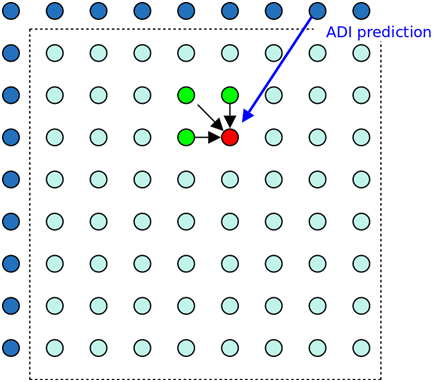
Both JCTVC-C101 and JCTVC-C270 have demonstrated coding performance improvement, with a similar stcuture. While the coding performance of JCTVC-C270 may be better, the cost is an increased complexity. This experiment is to test the fast encoding method to reduce the complexity and also by making a trade-off between prediction parameter signaling and estimation, to achieve a coding efficiency improvement to the extent shown by JCTVC-C270 with a complexity close to or lower than JCTVC-C101.

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### JCTVC-A125, JCTVC-C213: Combined Intra Prediction, (BBC, Sharp, NEC)

The CIP is a low-complexity tool for providing improved intra prediction. CIP predictions comprise a weighted combination of an ANG prediction together with a pixel-by-pixel local mean prediction. It provides pixel-by-pixel adaptation but is a simpler tool than, for example, local template matching approaches.



**ANG prediction**

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

The local mean is constructed as the average of pixel values to the left, top-left and above the current picture. In the decoder and within the local decoder in the encoder, these values are the reconstructed values after inverse quantization and transform. In the encoder, the reconstructed values are not available because quantization and transform of the prediction residue have not yet been performed, so original values are used This local mean prediction is therefore different between forward prediction (encoder only) and reconstruction (encoder and decoder).

The combination factor is a 5-bit number between 0 and 31/32 which determines the proportion of local mean in the prediction. Since this number is less than 1, the prediction/reconstruction difference noise is damped, and pixel-by-pixel prediction adaptation is possible without noise blow-up. The ANG component provides an overall prediction direction and the local mean prediction provides local adaptation.

In TMuC, for each CU, a single CIP flag is sent for all PUs. If set, the flag indicates that CIP prediction is used, otherwise ANG prediction is used.

#### Study

Implementation of CIP in TMuC was suboptimal and in [?] it has been shown that preliminary integration improvements lead to higher coding gains by a factor of 2-3, up to 1.2% BD rate reduction on Intra Low Complexity. The purpose of this study is to investigate further configuration and integration of the CIP tool, including, for example: compatibility with newly defined parameters for RQT, prediction for edge blocks, coding of syntax elements, more efficient implementation and weighting adjustments.

The experiments will be performed on TM or TMuC (adapted to TM setting), depending on availability, based on the recommended configurations.

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## CE6.c: Edge based Intra Prediction

### JCTVC-C169, JCTTVC-C176 (Sony, Sharp)

Image signal prediction in an arbitrary direction has already been included in TMuC. In TE 6.b the performance of DCIM algorithm was reported. This method has been further studied during the cross verification period and a method for encoding of prediction mode signal has been proposed.

There are two proposed techniques related to so-called Edge based intra prediction, which are being investigated in JCT-VC in the context of Tool Experiment. One is proposed in JCTVC-A114 and it has been incorporated in TMuC. The other is called DCIM (Differential Coding of Intra Modes), and it was proposed in JCTVC-B109. DCIM has been evaluated in TE (TE6: Intra Prediction Improvement). Figure below shows a high conceptual level of this approach:



Figure : An illustration of the construction of the new modes (a) computation of the neighbors' suggested direction.

The common feature of this two techniques is that they derive a direction by analyzing the gradient of each pixel in the part of the neighboring regions. The derived direction is used to derive one or more of the intra prediction modes available for the target partition. In A114, the prediction mode corresponding to the direction is used instead of DC mode when edge seems strong enough. In B109, several sub-directions are set around the derived direction (main direction), and intra prediction modes corresponding to the main and sub directions are added to the original intra prediction modes. A flag is introduced to indicate whether the additional or the original modes are used as the candidates of the intra prediction modes for the target partition. In this CE will plan to further investigate the followings:

1. Study on number of additional predictors in DCIM

In the current implementation of DCIM, 9 predictors are added to the conventional directional predictors. The 9 predictors include one main direction and 8 sub directions. Considering that number of the traditional directional predictors differs depending on the partition size, we assume that such configuration can also be applied to the additional predictors in DCIM. Therefore, we investigate the effect of changing the number of additional predictors depending on the partition size.

1. Potential combination with Block Based & Line/Pixel Based Intra Prediction Tools
2. Apply the method for chroma
3. Investigate the complexity/coding efficiency tradeoffs

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## CE6.d: Parallel Intra Coding

### JCTVC-B112 (Sharp Labs. of America)

The goal of the parallel prediction unit is to define a group of pixels that are intra-coded, and where the intra-coding may be done in a parallel fashion has been designed to take advantage of the available edge information in the reconstructed neighborhood of the block to be coded. Using an intra-4x4 prediction strategy, there is a partition to sixteen 4x4 blocks in (b) into two sets of blocks. Each of these partitions contained eight blocks, and a checker-board arrangement such as shown in Figure 5 is used. In the Figure, blocks in the first set are shown with shading, while blocks in the second set are shown in white.



Figure : Illustration of partitioning a macro-block into two sets of blocks for parallel intra prediction. Blocks denoted with shading are assigned to the first partition; blocks shown in white are assigned to the second partition.

In the proposal, blocks in the first set are predicted from pixel values at the border of the PPU. Blocks in the second set are predicted from neighboring blocks that are either outside of the PPU or belong to the first set. Prediction of the second set of blocks uses additional prediction directions that are defined as combinations of the right and bottom neighbors, as well as neighbors to the left and above. The additional prediction modes are rotations of the existing modes. So, for example, if the historical nine modes of H.264/AVC are enabled, then the additional modes are shown in Figure C2. In the experiment, we will use rotations of the prediction set in the tests. To best utilize the modes, we also allow the weighted combination of a rotated and un-rotated mode. (For example, a horizontal left and horizontal right.) The weighting is expressed as

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where *w* denotes the weight and may be a fractional number, and *p*1(*y*,*x*) and *p*2(*y*,*x*) denote the predicted values using the first mode and a second mode, respectively.

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| **17**  **10**  **15**  **13**  **14**  **9**  **1**  **8**  **12**  **3**  **7**  **0**  **5**  **4**  **6**  **16**  **17**  **10**  **15**  **13**  **14**  **9**  **1**  **8**  **12**  **3**  **7**  **0**  **5**  **4**  **6**  **16** | |  |  | | --- | --- | | Mode | Name of Mode | | 9 | Vertical 2 | | 10 | Horizontal 2 | | 11 | DC 2 | | 12 | Diagonal Down Left 2 | | 13 | Diagonal Down Right 2 | | 14 | Vertical Right 2 | | 15 | Horizontal Down 2 | | 16 | Vertical Left 2 | | 17 | Horizontal Up 2 | |

Figure 6: - Additional intra prediction modes introduced in the proposed technique.

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