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| **Joint Collaborative Team on Video Coding (JCT-VC)**  **of ITU-T SG16 WP3 and ISO/IEC JTC1/SC29/WG11**  5th Meeting: Geneva, 16-23 March, 2011 | Document: JCTVC-E318\_r1  WG11 Number: m19846 |

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| *Title:* | **Differential Coding of Intra Modes** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Proposal | | |
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# Abstract

Differential Coding of Intra Modes (DCIM) was presented as an effective Intra prediction tool especially for sequences with a lot of dominant edge information. In this document a summary of the current implementation of DCIM and its evolution since the original proposal, as well as its experimental results are presented. On average, using this technique, 1.4% and 1.6% gain is achieved compared to HM 2.0 anchors for High Efficiency (HE) and Low Complexity (LC) settings, respectively.

# Algorithm description

DCIM uses neighborhood edge estimation to predict the Intra prediction direction and differentially encodes the selected direction with respect to the predicted direction (i.e., given by the edge). This enables a higher accuracy in the Intra prediction directions (modes) without substantially increasing the mode signaling overhead. An additional flag bit is transmitted per Prediction Unit (PU) to signal to the decoder whether DCIM is used. The decoder needs to perform edge detection only for the PUs for which the DCIM flag is on. Details of various parts of the proposed technique are described below.

## Edge Derivation

In order to find the dominant direction in the neighborhood of the block to be predicted, edge detection is used both at the encoder and decoder. A neighborhood of 2-pixels wide is considered in the reconstructed area around the block to be Intra predicted. Then, the following 2-tap filters are applies in the considered region to find the local image gradients.



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Figure 1 illustrated the block to be predicted and the derived local image gradients in the reconstructed neighborhood. Next, to filter out noise and find a dominant direction the following two integer values are computed

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where,  are the two components of the image gradient resulted from filtering with  and , and  represents the reconstructed neighborhood considered for edge derivation. The ratio  and the



Figure 1. An example of local image gradients in the reconstructed neighborhood.

signs of  and  are used with a look-up table of size 32 to find the index of the direction to be used for Intra prediction. Since  and  are both integers an 8-bit precision is considered for their ratio, i.e., . The index of the dominant direction is a value between 0-127, each corresponding to a direction of a line drawn between an integer location on the boundary of a 32x32 rectangle and its center.

## Prediction

Once the index of the dominant direction is known the process of Intra prediction for the block is conducted similarly to that of Unified Intra (UI) directions. The only difference is that there are 32 possible UI directions (slopes) while the number of possible edge-derived directions is 128. Consequentially, the prediction for both edge-derived directions and UI directions can be performed using one function.

## DCIM directions

When DCIM is used, the number of UI prediction modes is always less than or equal to 17 modes for all PU sizes. However, in addition to the edge-derived direction and UI directions, a number of other DCIM directions (typically 4 or 5 directions on each side) are also considered around the detected edge. These direction consist of approximately equally distanced directions that are closest to the derived edge. Figure 2 demonstrated this concept.

## Bi-prediction

Using the edge information, additional bi-prediction modes can also be considered. Two edges can be derived, one from the top neighborhood and the other from the left. Note that the calculation of these two edge only marginally adds to the computation of DCIM since the values of  and  from the top and left regions can be computed separately and added together when a combined dominant edge direction is to be calculated. The two directions derived from the top and left regions are then used for a bi-prediction similarly to [JCTVC-D108]. Currently, only one bi-prediction mode is implemented.

## Interpolation

Conducting directional prediction using an arbitrary direction, often requires non-integer pixel values in the reconstructed boundary of the block. The values of these fractional-pel locations are therefore obtained using interpolation. In the current HM 2.0 a linear (2-pel) interpolation method is utilized. However, the DCIM directions perform better when used with a more accurate interpolation, such as 32 4-tap interpolation filters (shown in ). The main DCIM direction (edge-derived) always uses these 4-tap filters. However, the rest of the directions use both 4-tap and the default linear interpolation based on their mode number and a fixed look-up table. An application of this filter was reported in document JCTVC-D391.

Table 1. 4-tap interpolation filters (values scaled by 256).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Fractional-pel location | Filter coefficient | | | |
| 0/32 | 0 | 256 | 0 | 0 |
| 1/32 | -3 | 252 | 8 | -1 |
| 2/32 | -5 | 247 | 17 | -3 |
| 3/32 | -7 | 242 | 25 | -4 |
| 4/32 | -9 | 236 | 34 | -5 |
| 5/32 | -10 | 230 | 43 | -7 |
| 6/32 | -12 | 224 | 52 | -8 |
| 7/32 | -13 | 217 | 61 | -9 |
| 8/32 | -14 | 210 | 70 | -10 |
| 9/32 | -15 | 203 | 79 | -11 |
| 10/32 | -16 | 195 | 89 | -12 |
| 11/32 | -16 | 187 | 98 | -13 |
| 12/32 | -16 | 179 | 107 | -14 |
| 13/32 | -16 | 170 | 116 | -14 |
| 14/32 | -17 | 162 | 126 | -15 |
| 15/32 | -16 | 153 | 135 | -16 |
| 16/32 | -16 | 144 | 144 | -16 |
| *i*/32, *i* | Mirror of filter for (32-*i*)/32 | | | |

## Signaling

For Intra coding of the luma component for PU sizes of 4x4,8x8, 16x16 and 32x32 a 1-bit flag is first transmitted to indicated whether a DCIM or a UI mode is to follow. In case of DCIM mode, truncated unary codes are used to signal the distance of the intended mode with respect to the derived direction. If the distance is greater than zero (other than the derived mode) a sign bit is also transmitted to signal directions to the right or left of the derived direction. In case of an UI direction, no change has been made in the signaling of the modes except that the most probable mode is always assumed to be DC (mode 2).



Figure 2. Additional DCIM directions considered around the dominant edge direction.

For chroma components a separate dominant edge is derives (per channel). However, there are no additional DCIM directions. A 1-bit flag is inserted immediately after "the same as luma" to indicate whether DCIM derived edge for chroma shall be used.

The bit assignment to each intra modes are summarized in the following tables. Note that, for 64x64 PU, DCIM modes are not used thus dcim\_flag is omitted.

Table 2. Bit assignment for intra modes for Luma   
(Index m represents UI modes and index k represents directions used for DCIM. M and K are defined depending on PU size; M=2 for 64x64 PU and M=16 for other PU sizes. K=2 for 32x32 PU and K=5 for other PU sizes.)

|  |  |  |  |
| --- | --- | --- | --- |
| **Intra mode** | | **Bit assignment** | |
| **DCIM/UI** |  | **dcim\_flag** | **rem\_bits** |
| UI | m=0,1, .., M | 0 | (same as HM2.0) |
| DCIM | k=0 | 1 | 1 |
| DCIM | Bi-prediction | 1 | 01 |
| DCIM | k=±1, ±2, ..., ±K | 1 | 00 + unary(abs(k)-1) + sign(k) |

Table 3. Bit assignment for intra modes (Chroma)

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| --- | --- | --- | --- | --- |
| **Intra mode** | | **Bit assignment** | | |
| **DCIM/UI** |  | **luma\_flag** | **dcim\_flag** | **rem\_bits** |
| UI | m=4 (same as luma) | 1 | - | - |
| DCIM | k=0 | 0 | 1 |  |
| UI | m=0, 1, 2, 3 | 0 | 0 | (same as HM2.0) |

# Results

The proposed algorithm was implemented into the HM software 2.0. Test conditions are as defined in Core Experiment 6 and the results are compared with the original HM 2.0 software. Table 2 Shows the average BD-rates of DCIM when compared to HM 2.0 Anchors for both High Efficiency and Low Complexity settings.

Table . performance of DCIM compared to HM 2.0.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | 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 | -0.3 | -1.0 | -0.2 | -0.3 |
| Class B | -1.3 | -0.9 | -1.0 | -1.2 | -1.3 | -1.5 |
| Class C | -1.8 | -1.5 | -1.8 | -2.2 | -1.9 | -2.1 |
| Class D | -1.3 | -0.9 | -1.0 | -1.7 | -1.3 | -1.4 |
| Class E | -1.8 | -1.7 | -1.6 | -2.3 | -0.5 | -0.9 |
| All | -1.4 | -1.1 | -1.1 | -1.6 | -1.1 | -1.3 |
| Enc Time[%] | 107% | | | 112% | | |
| Dec Time[%] | 103% | | | 108% | | |

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| Table 4. DCIM + Planar | | | | | | | | |
|  | 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 | | 1.1 | 1.4 | -1.4 | 0.4 | | 0.8 |
| Class B | -2.1 | | -0.3 | -0.2 | -1.7 | -1.2 | | -1.0 |
| Class C | -2.2 | | -0.6 | -0.6 | -2.6 | -1.8 | | -1.9 |
| Class D | -1.9 | | -0.1 | 0.1 | -2.1 | -1.3 | | -1.3 |
| Class E | -2.8 | | -0.9 | -0.3 | -2.9 | -0.4 | | -0.9 |
| All | -2.0 | | -0.1 | 0.1 | -2.1 | -0.9 | | -0.9 |
| Enc Time[%] | 109% | | | | 113% | | | |
| Dec Time[%] | 105% | | | | 111% | | | |
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# Patent rights declaration(s)

**Sony, SHARP, Panasonic, and Toshiba Corporation may have IPR relating to the technology described in this contribution and, conditioned on reciprocity, is prepared to grant licenses under reasonable and non-discriminatory terms as necessary for implementation of the resulting ITU-T Recommendation | ISO/IEC International Standard (per box 2 of the ITU-T/ITU-R/ISO/IEC patent statement and licensing declaration form).**