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| **Joint Collaborative Team on Video Coding (JCT-VC)**  **of ITU-T SG16 WP3 and ISO/IEC JTC1/SC29/WG11**  4th Meeting: Daegu, KR, 20-28 January, 2011 | Document: JCTVC-D259\_r2 |

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| --- | --- | --- | --- |
| *Title:* | **CE6: Summary Report of Core Experiments for Intra Prediction** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Report | | |
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# Abstract

This contribution provides a summary of Core Experiment 6, Intra Prediction Improvements. From a total of 9 proposed CEs 8 had been cross-checked with full match by at least on organization. For cross checking, the recommended test conditions of intra-only were used for both high compression efficiency and low complexity as defined in the document JCTVC-C506\_r3.

# Introduction

Intra prediction improvement core experiments was divided into 4 categories

1. CE6.a: Block Based Intra Prediction
2. CE6.b: Line/Pixel based Intra Prediction
3. CE6.c: Edge Based Intra Prediction
4. CE6.d: Parallel Intra Coding

Table 1 summarizes the technologies tested together with the list of the proponents and cross-checkers:

|  |  |  |  |
| --- | --- | --- | --- |
|  | Technology | Proponent | Cross-checker(s) |
| CE6.a.1 | Bidirectional Intra Prediction | Toshiba  JCTVC-C079  JCTVC-D108 | Sharp Labs. of America JCTVC-D066 Nokia JCTVC-D196 |
| CE6.a.3 | Chroma intra prediction from reconstructed luma samples | Samsung  JCTVC-C206  JCTVC-D350 | Microsoft JCTVC-D145  Toshiba JCTVC-D110  Qualcomm JCTVC-D398 |
| CE6.a.5 | Optimizing the combination of current intra predictors | Santa Clara University  JCTVC-C111  JCTVC-D026 | Samsung JCTVC-D348 |
| CE6.b.1 | Short distance intra prediction | Huawei/Hisilicon & Microsoft  JCTVC-C101, JCTVC-C270  JCTVC-D299 | LGE JCTVC-D124 |
| CE6.b.2 | Combined Intra Prediction | BBC  JCTVC-C213  JCTVC-D191 | Sharp Labs. of America JCTVC-D065  NEC JCTVC-D204 |
| CE6.c | Differential coding of intra modes (DCIM) | Sharp &Sony  JCTVC-C169, JCTVC-C176  JCTVC-D279 | NEC JCTVC-D205  Panasonic JCTVC-D218  NHK JCTVC-D177 |
| CE6.d | Parallel Intra Coding | Sharp Labs. of America  JCTVC-B112  JCTVC-D074 | Toshiba JCTVC-D111 |

# Summary of Experimental Results

## Software

All tests are run based on TMuC0.9 anchor.

## Complexity

For complexity measurements, the encoding and decoding times have been the most frequently reported measures.

## Visual

Santa Clara University for CE6.a.5 (JCTVC-D026)

NEC has conducted visual evaluation of DCIM for CE6.c (JCTVC-D205)

## Coding Efficiency

**CE6.a.1** Bidirectional Intra Prediction

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -1.6 | -1.0 | -1.1 | -2.3 | -1.7 | -1.7 |
| Class B | -1.6 | -1.0 | -1.1 | -2.0 | -1.5 | -1.5 |
| Class C | -1.4 | -0.7 | -0.7 | -1.7 | -1.1 | -1.1 |
| Class D | -1.1 | -0.5 | -0.5 | -1.6 | -0.9 | -0.9 |
| Class E | -1.7 | -1.3 | -1.1 | -2.6 | -2.2 | -1.8 |
| All | -1.4 | -0.9 | -0.9 | -2.0 | -1.4 | -1.4 |
| Enc Time[%] | 107% | | | 114% | | |
| Dec Time[%] | 106% | | | 110% | | |

**CE6.a.3** Chroma intra prediction from reconstructed luma samples

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **T1: LM\_5\_modes** | | | | | | | | | | | | | | | |
|  | Intra | | | | | | Intra LoCo | | | | | | | | |
| Y BD-rate | U BD-rate | | | V BD-rate | | Y BD-rate | | | U BD-rate | | V BD-rate | | | |
| Class A | -1.4 | -7.4 | | | -3.6 | | -1.1 | | | -7.7 | | -3.1 | | | |
| Class B | -1.5 | -7.8 | | | -4.2 | | -1.3 | | | -8.1 | | -3.8 | | | |
| Class C | -1.9 | -7.7 | | | -8.2 | | -1.9 | | | -7.1 | | -7.7 | | | |
| Class D | -1.3 | -5.5 | | | -5.3 | | -1.3 | | | -5.1 | | -4.7 | | | |
| Class E | -1.1 | -4.6 | | | -5.2 | | -0.5 | | | -3.4 | | -4.6 | | | |
| All | -1.5 | -6.7 | | | -5.5 | | -1.3 | | | -6.4 | | -4.9 | | | |
| Enc Time[%] | 100% | | | | | | 101% | | | | | | | | |
| Dec Time[%] | 101% | | | | | | 101% | | | | | | | | |
|  |  |  | | |  | |  | | |  | |  | | | |
|  |  |  |  | | | |  | |  | | | | |  | |
|  | | | | | | | | | | | | | | | |
| **T2: LM\_3\_modes** | | | | | | | | | | | | | | | |
|  | Intra | | | | | | Intra LoCo | | | | | | | | |
| Y BD-rate | U BD-rate | | | V BD-rate | | Y BD-rate | | | U BD-rate | | V BD-rate | | | |
| Class A | -1.4 | -7.3 | | | -3.6 | | -1.1 | | | -7.5 | | -2.8 | | | |
| Class B | -1.5 | -7.6 | | | -3.9 | | -1.2 | | | -7.7 | | -3.5 | | | |
| Class C | -1.8 | -7.5 | | | -8.0 | | -1.7 | | | -6.8 | | -7.3 | | | |
| Class D | -1.2 | -5.0 | | | -5.0 | | -1.1 | | | -4.7 | | -4.4 | | | |
| Class E | -1.1 | -4.3 | | | -5.1 | | -0.5 | | | -3.6 | | -4.0 | | | |
| All | -1.4 | -6.4 | | | -5.2 | | -1.2 | | | -6.1 | | -4.5 | | | |
| Enc Time[%] | 96% | | | | | | 94% | | | | | | | | |
| Dec Time[%] | 100% | | | | | | 101% | | | | | | | | |
|  | | | | | | | | | | | | | | | | |
| **T3: code-word re-assigment** | | | | | | | | | | | | | | | | |
|  | Intra | | | | | | Intra LoCo | | | | | | | | | |
| Y BD-rate | U BD-rate | | V BD-rate | | | Y BD-rate | | | U BD-rate | | V BD-rate | | | | |
| Class A | -0.8 | 0.1 | | 0.3 | | | -0.6 | | | -0.3 | | -0.1 | | | | |
| Class B | -0.7 | 0.1 | | 0.1 | | | -0.6 | | | -0.5 | | -0.4 | | | | |
| Class C | -0.7 | 0.1 | | 0.2 | | | -0.7 | | | -0.5 | | -0.4 | | | | |
| Class D | -0.5 | 0.2 | | 0.3 | | | -0.5 | | | -0.3 | | -0.3 | | | | |
| Class E | -1.0 | -0.6 | | -0.3 | | | -0.5 | | | -0.1 | | -0.2 | | | | |
| All | -0.7 | 0.0 | | 0.1 | | | -0.6 | | | -0.4 | | -0.3 | | | | |
| Enc Time[%] | 99% | | | | | | 99% | | | | | | | | | |
| Dec Time[%] | 100% | | | | | | 100% | | | | | | | | | |
|  |  |  | |  | | |  | | |  | |  | | | | |
| **T4: DM + DC** | | | | | | | | | | | | | | |
|  | Intra | | | | | | | Intra LoCo | | | | | | |
| Y BD-rate | U BD-rate | | | | V BD-rate | | Y BD-rate | | | U BD-rate | | V BD-rate | |
| Class A | -0.8 | -0.3 | | | | 0.0 | | -0.7 | | | 0.4 | | 1.4 | |
| Class B | -0.6 | 0.3 | | | | 0.4 | | -0.7 | | | 0.6 | | 1.4 | |
| Class C | -0.6 | 0.5 | | | | 0.6 | | -0.5 | | | 0.7 | | 0.9 | |
| Class D | -0.4 | 0.8 | | | | 0.7 | | -0.3 | | | 1.0 | | 0.9 | |
| Class E | -1.0 | -0.2 | | | | -0.2 | | -0.6 | | | 0.8 | | 1.9 | |
| All | -0.6 | 0.3 | | | | 0.4 | | -0.5 | | | 0.7 | | 1.3 | |
| Enc Time[%] | 93% | | | | | | | 90% | | | | | | |
| Dec Time[%] | 100% | | | | | | | 100% | | | | | | |

**CE6.a.5** Optimizing the combination of current intra predictors

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| TEST#1 | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -0.2 | -0.2 | -0.2 | -0.5 | -0.3 | -0.4 |
| Class B | -0.2 | -0.2 | -0.3 | -0.5 | -0.4 | -0.4 |
| Class C | -0.1 | -0.1 | -0.1 | -0.2 | -0.2 | -0.2 |
| Class D | 0.0 | 0.0 | 0.0 | -0.2 | -0.2 | -0.2 |
| Class E | -0.4 | -0.4 | -0.5 | -0.8 | -0.8 | -0.6 |
| All | -0.2 | -0.2 | -0.2 | -0.4 | -0.4 | -0.3 |
| Enc Time[%] | 102% | | | 99% | | |
| Dec Time[%] | 97% | | | 99% | | |

UIP with MPS compared with Anchor

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| TEST#2 | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -0.1 | -0.2 | -0.1 | 0.7 | 0.6 | 0.4 |
| Class B | -0.2 | -0.3 | -0.3 | 0.7 | 0.5 | 0.3 |
| Class C | 0.0 | -0.1 | -0.1 | 1.1 | 0.8 | 0.7 |
| Class D | 0.0 | 0.0 | 0.0 | 1.0 | 0.7 | 0.6 |
| Class E | -0.4 | -0.3 | -0.5 | 0.7 | 0.1 | 0.4 |
| All | -0.1 | -0.2 | -0.2 | 0.9 | 0.6 | 0.5 |
| Enc Time[%] | 103% | | | 101% | | |
| Dec Time[%] | 98% | | | 97% | | |

UIP with MPS and Planar enabled compared with Anchor:

**CE6.b.1** Short distance intra prediction

**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 | -3.7 | -1.9 | -1.9 | -4.9 | -3.6 | -3.9 |
| Class B | -3.2 | -1.5 | -1.7 | -4.9 | -2.6 | -3.5 |
| Class C | -5.5 | -2.9 | -3.1 | -7.4 | -4.0 | -4.8 |
| Class D | -5.6 | -3.0 | -3.0 | -7.1 | -4.1 | -4.5 |
| Class E | -4.8 | -3.2 | -3.0 | -5.8 | -7.2 | -6.3 |
| All | -4.6 | -2.5 | -2.5 | -6.1 | -4.1 | -4.5 |
| Enc Time[%] | 200% | | | 182% | | |
| Dec Time[%] | 104% | | | 112% | | |

**Faster Configuration**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | | Intra LoCo | | |
| Y BD-rate | | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -3.5 | -1.9 | | -1.9 | -4.5 | -3.3 | -3.4 |
| Class B | -3.0 | -1.4 | | -1.7 | -4.4 | -2.5 | -3.2 |
| Class C | -5.2 | -2.8 | | -3.1 | -7.0 | -3.8 | -4.4 |
| Class D | -5.4 | -2.9 | | -2.9 | -6.8 | -3.9 | -4.2 |
| Class E | -4.5 | -3.0 | | -2.7 | -5.3 | -6.3 | -5.6 |
| All | -4.3 | -2.4 | | -2.5 | -5.7 | -3.8 | -4.1 |
| Enc Time[%] | 161% | | | | 146% | | |
| Dec Time[%] | 100% | | | | 105% | | |

CE6.b.2

Combined Intra Prediction High Complexity (HC) settings

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -2.2 | -5.7 | -5.7 | -3.7 | -4.5 | -4.3 |
| Class B | -1.3 | -3.3 | -3.4 | -2.3 | -2.8 | -2.8 |
| Class C | -1.4 | -2.2 | -2.3 | -2.1 | -1.8 | -1.8 |
| Class D | -1.3 | -1.9 | -1.9 | -2.1 | -1.6 | -1.6 |
| Class E | -1.8 | -4.4 | -4.3 | -3.3 | -3.5 | -3.6 |
| All | -1.5 | -3.2 | -3.2 | -2.5 | -2.6 | -2.6 |
| Enc Time[%] | 175% | | | 207% | | |
| Dec Time[%] | 104% | | | 102% | | |

Combined Intra Prediction Medium Complexity (MC) settings

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -1.5 | -5.4 | -5.6 | -2.9 | -6.1 | -6.0 |
| Class B | -0.5 | -2.7 | -2.8 | -0.8 | -4.0 | -4.1 |
| Class C | 0.2 | -2.3 | -2.3 | 0.0 | -2.8 | -2.8 |
| Class D | 0.1 | -2.0 | -2.0 | -0.3 | -2.4 | -2.4 |
| Class E | -0.5 | -3.8 | -3.6 | -1.7 | -5.2 | -5.1 |
| All | -0.3 | -2.9 | -3.0 | -0.9 | -3.8 | -3.8 |
| Enc Time[%] | 107% | | | 113% | | |
| Dec Time[%] | 102% | | | 108% | | |

Combined Intra Predcition Low Complexity (LC) settings

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -1.2 | -3.8 | -3.9 | -2.4 | -4.5 | -4.3 |
| Class B | -0.5 | -1.8 | -1.9 | -0.6 | -3.0 | -3.1 |
| Class C | 0.1 | -1.8 | -1.8 | 0.0 | -2.3 | -2.4 |
| Class D | 0.0 | -1.6 | -1.7 | -0.3 | -2.0 | -2.1 |
| Class E | -0.4 | -2.6 | -2.4 | -1.3 | -3.5 | -3.6 |
| All | -0.3 | -2.1 | -2.1 | -0.7 | -2.9 | -2.9 |
| Enc Time[%] | 100% | | | 104% | | |
| Dec Time[%] | 100% | | | 104% | | |

**CE6.c** Differential Coding of Intra Modes

**Experiment-1**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -1.7 | -0.6 | -0.3 | -1.5 | -0.8 | -0.4 |
| Class B | -2.1 | -1.1 | -1.2 | -2.2 | -1.8 | -1.9 |
| Class C | -2.4 | -1.1 | -1.2 | -2.9 | -1.9 | -2.0 |
| Class D | -1.5 | -0.4 | -0.3 | -1.8 | -0.8 | -1.0 |
| Class E | -3.1 | -2.2 | -1.9 | -3.1 | -1.5 | -1.7 |
| All | -2.1 | -1.1 | -1.0 | -2.3 | -1.4 | -1.5 |
| Enc Time[%] | 109% | | | 115% | | |
| Dec Time[%] | 106% | | | 123% | | |

**Experiment II (17 UI Directions + MPM Improvement)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Intra | | | Intra LoCo | | |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -1.8 | -0.9 | -0.5 | -1.8 | -0.8 | -0.4 |
| Class B | -2.3 | -1.4 | -1.4 | -2.6 | -2.0 | -2.0 |
| Class C | -2.5 | -1.3 | -1.4 | -3.0 | -1.9 | -2.1 |
| Class D | -1.6 | -0.5 | -0.6 | -2.0 | -0.8 | -1.2 |
| Class E | -3.3 | -2.1 | -1.9 | -3.2 | -1.5 | -1.6 |
| All | -2.3 | -1.2 | -1.2 | -2.6 | -1.5 | -1.6 |
| Enc Time[%] | 106% | | | 106% | | |
| Dec Time[%] | 106% | | | 117% | | |