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| *Title:* | **Non-CE2: encoder improvements on IBC search** | | |
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# Abstract

This contribution proposed several encoder improvements about Intra Block Copy (IBC) search. It mainly includes improved predictors based IBC search using block vectors from the previous picture, new hash generation method for hash based IBC search, modified early termination for IBC search and changing color space used in hash based IBC search for RGB format encoding. Compared to SCM-3.0 anchors, for 444 lossy coding, the proposed scheme reportedly achieves average {Y, U, V} BD rate gain of {-2.1%, -2.0%, -1.9%}, {-2.0%, -1.8%, -1.8%} and {-2.1%, -1.5%, -1.4%} for the category (RGB/YUV, text & graphics with motion, 1080p&720p) for AI, RA and LD, respectively. And the 444 lossless coding reportedly achieves total bit-rate saving of -0.9%, -0.5% and -0.4% for the category (RGB/YUV, text & graphics with motion, 1080p&720p) for AI, RA and LD, respectively.

# Introduction

In order to improve IBC search, the following six non-normative changes are proposed in this proposal.

1. Adding one BV predictor from previous coded picture to improve predictor based IBC search

In AI coding configuration, one additional BV predictor from previous coded picture is added for predictor based IBC search. The collocated block (e.g. block C and D) in previous picture is checked. If it is IBC coded, the BV will be used as predictor for current block X shown in Figure 1.



Figure . Additional BV predictor (BVP) is added from previous coded picture

1. Modified hash generation method for hash based IBC search

For each 8x8 block, it is partitioned into 12 sub-blocks depicted as Figure 2. The DC of each sub-block (*DC(SBi)*) and the DC of the block (*DC(B)*) are calculated. The gradient of the block (*Grad(B)*) is also calculated. One flag (*F(SBi)*) is produced using Equation (1) by comparing local feature *DC(SBi)* and global feature *DC(B).*

(1)

The 12 flags and 3 MSB bits of *Grad(B)* are concatenated to generate 15 bits hash value, which is depicted by Equation (2).

(2)



Figure . 8x8 block partitioning

The inter hash is also changed to 15 bits to align with the number of bits used in IBC hash. 15-bit inter hash will reduce the encoding complexity because it results in more early termination during 2Nx2N inter hash search with negligible BD loss (<=0.02%, YUV TGM category of RA configuration).

1. Changing the color space using in hash based IBC search

In the encoding with RGB format, the color spaces used in spatial IBC search and the color space used in hash generation in the current reference software (SCM-3.0) are different. We propose to use YCgCo to generate hash value to align with that used in predictors based IBC search and spatial IBC search.

1. Adding Nx2N/2NxN partition checking for large CU size

In SCM-3.0, Nx2N and 2NxN partitions of IBC mode are not checked for 32x32 and 16x16 CU. We propose to add these two partitions using only predictors based IBC search to improve the performance. To restrict the encoding complexity, Nx2N is checked for all slices, and 2NxN is only checked for inter coded slices.

1. Changing the early termination condition for IBC search

In SCM-3.0, if quantized residual of current best mode are all zeros, then IBC search will be skipped. This early termination may be too aggressive in some cases. We propose to modify the early termination for IBC search using the following conditions:

1. If the current best mode is skip mode, then all IBC search will be skipped;
2. After predictor based IBC search is performed, if the current best mode is IBC and quantized residual are all zeros, then spatial and hash based IBC search will be skipped.
3. Changing the search order in 1-D spatial IBC search

The vertical search order in 1-D spatial IBC search is reversed to align with that in horizontal direction search. Figure 3 (a) shows the search order in SCM-3.0, and Figure 3 (b) shows the proposed search order.

 

1. 1-D spatial search in SCM-3.0 (b) Proposed 1-D spatial search

Figure . Search order change in 1-D spatial search

# Simulation results

The compression performance of the proposed method is compared with SCM-3.0 anchors, using the CTC test conditions [1]. Table 1 and Table 2 report the average BD rate reduction for 444 and 420 lossy coding, respectively. Table 3 and Table 4 report the average rate reduction for 444 and 420 lossless coding, respectively. The accompanying spreadsheets are provided for further details.

As shown in Table 1 compared with SCM-3.0 anchors, for 444 lossy coding, the proposed IBC search achieves average {Y, U, V} BD rate gain of {-2.1%, -2.0%, -1.9%}, {-2.1%, -2.1%, -2.0%} and {-2.1%, -1.7%, -1.5%} for the category (YUV, text & graphics with motion, 1080p&720p) for AI, RA and LD, respectively. Similar gains for the category (RGB, text & graphics with motion, 1080p&720p) are observed. As shown in Table 2, compared with SCM-3.0 anchors, for 420 lossy coding, the proposed IBC search achieves average {Y, U, V} BD rate gain of {-2.7%, -2.7%, -2.6%}, {-1.0%, -0.9%, -0.9%} and {-0.8%, -1.3%, -1.6%} for the category (Text & graphics with motion, 720p) for AI, RA and LD, respectively. For most testing conditions, a small reduction in encoding time of (1-6%) is also observed.

As shown in Table 3, compared with SCM-3.0 anchors, for 444 lossless coding, the proposed IBC search achieves total bit-rate saving of -0.9%, -0.5% and -0.4% for the category (RGB/YUV, text & graphics with motion, 1080p&720p) for AI, RA and LD, respectively. As shown in Table 4, for 420 lossless coding, the proposed IBC search achieves total bit-rate saving of -1.9%, -0.2% and -0.1% for the category (Text & graphics with motion, 720p) for AI, RA and LD, respectively.

We also applied the encoder improvements based on the unified IBC and inter framework (CE-2 Test-1 [2][3]). In this test, the improvement (4) is not enabled, and BV and MV bi-prediction search is applied. Table 5 and Table 6 report the average BD rate reduction for 444 and 420 lossy coding in CE-2 Test-1 platform. Table 7 and Table 8 report the average rate reduction for 444 and 420 lossless coding in CE-2 Test-1 platform, respectively.

Table 1. Average BD rate reduction for 444 lossy coding compared with SCM-3.0 anchors

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra** | | | **Random Access** | | | **Low delay B** | | |
|  | G/Y | B/U | R/V | G/Y | B/U | R/V | G/Y | B/U | R/V |
| RGB, text & graphics with motion, 1080p & 720p | -2.0% | -1.9% | -1.9% | -2.0% | -1.6% | -1.5% | -2.0% | -1.3% | -1.3% |
| RGB, mixed content, 1440p & 1080p | -1.4% | -1.3% | -1.4% | -0.6% | -0.6% | -0.7% | -0.6% | -0.3% | -0.4% |
| RGB, Animation, 720p | 0.0% | -0.1% | -0.1% | 0.0% | 0.0% | 0.0% | 0.0% | -0.1% | -0.2% |
| RGB, camera captured, 1080p | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| YUV, text & graphics with motion, 1080p & 720p | -2.1% | -2.0% | -1.9% | -2.1% | -2.1% | -2.0% | -2.1% | -1.7% | -1.5% |
| YUV, mixed content, 1440p & 1080p | -1.2% | -1.1% | -1.1% | -0.8% | -0.6% | -0.6% | -1.0% | -0.9% | -0.7% |
| YUV, Animation, 720p | -0.1% | -0.2% | -0.2% | -0.2% | -0.4% | 0.0% | 0.0% | 0.1% | 0.1% |
| YUV, camera captured, 1080p | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | -0.1% | -0.1% | 0.0% | 0.0% |
| Enc Time[%] | 99% | | | 96% | | | 95% | | |
| Dec Time[%] | 95% | | | 95% | | | 97% | | |

Table . Average BD rate reduction for 420 lossy coding compared with SCM-3.0 anchors

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra** | | | **Random Access** | | | **Low delay B** | | |
|  | G/Y | B/U | R/V | G/Y | B/U | R/V | G/Y | B/U | R/V |
| Text & graphics with motion, 720p | -2.7% | -2.7% | -2.6% | -1.0% | -0.9% | -0.9% | -0.8% | -1.3% | -1.6% |
| Mixed content, 480p | -0.3% | -0.4% | -0.4% | -0.2% | -0.2% | -0.4% | 0.2% | -0.1% | 0.2% |
| Animation, 768p | -0.2% | -0.2% | -0.2% | -0.2% | 0.0% | 0.0% | -0.1% | 0.1% | 0.5% |
| Average of all sequences | -1.5% | -1.5% | -1.4% | -0.6% | -0.5% | -0.5% | -0.4% | -0.7% | -0.7% |
| Enc Time[%] | 106% | | | 95% | | | 94% | | |
| Dec Time[%] | 94% | | | 93% | | | 94% | | |

Table 3. Average BD rate reduction for 444 lossless coding compared with SCM-3.0 anchors

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra** | | | | **Random Access** | | | | **Low Delay B** | | | |
|  | Bit-rate change (Total) | Bit-rate change (Avg.) | Bit-rate change (Min) | Bit-rate change (Max) | Bit-rate change (Total) | Bit-rate change (Average) | Bit-rate change (Min) | Bit-rate change (Max) | Bit-rate change (Total) | Bit-rate change (Avg.) | Bit-rate change (Min) | Bit-rate change (Max) |
|  |
| RGB, text & graphics with motion, 1080p & 720p | -0.9% | -1.0% | -2.2% | -0.2% | -0.5% | -0.8% | -2.2% | 0.0% | -0.4% | -1.0% | -3.7% | 0.0% |
| RGB, mixed content, 1440p & 1080p | -0.9% | -0.9% | -1.5% | -0.3% | -0.1% | -0.1% | -0.3% | 0.0% | -0.1% | -0.1% | -0.1% | 0.0% |
| RGB, Animation, 720p | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| RGB, camera captured, 1080p | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| YUV, text & graphics with motion, 1080p & 720p | -0.9% | -1.0% | -2.2% | -0.3% | -0.5% | -0.7% | -2.2% | 0.0% | -0.4% | -0.9% | -3.7% | 0.0% |
| YUV, mixed content, 1440p & 1080p | -0.9% | -0.9% | -1.5% | -0.3% | -0.1% | -0.1% | -0.3% | 0.0% | -0.1% | -0.1% | -0.1% | 0.0% |
| YUV, Animation, 720p | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| YUV, camera captured, 1080p | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Enc Time[%] | 94% | | | | 95% | | | | 96% | | | |
| Dec Time[%] | 98% | | | | 102% | | | | 102% | | | |

Table . Average BD rate reduction for 420 lossless coding compared with SCM-3.0 anchors

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra** | | | | **Random Access** | | | | **Low Delay B** | | | |
|  | Bit-rate change (Total) | Bit-rate change (Average) | Bit-rate change (Min) | Bit-rate change (Max) | Bit-rate change (Total) | Bit-rate change (Average) | Bit-rate change (Min) | Bit-rate change (Max) | Bit-rate change (Total) | Bit-rate change (Average) | Bit-rate change (Min) | Bit-rate change (Max) |
|  |
| Text & graphics with motion, 720p | -1.9% | -1.9% | -3.1% | -0.7% | -0.2% | -0.3% | -0.5% | -0.1% | -0.1% | -0.1% | -0.1% | 0.0% |
| Mixed content, 480p | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Animation, 768p | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Average of all sequences | -0.6% | -0.9% | -3.1% | 0.0% | 0.0% | -0.2% | -0.5% | 0.0% | 0.0% | 0.0% | -0.1% | 0.0% |
| Enc Time[%] | 89% | | | | 92% | | | | 92% | | | |
| Dec Time[%] | 86% | | | | 100% | | | | 96% | | | |

Table 5. Average BD rate reduction for 444 lossy coding in CE-2 Test-1 platform compared with SCM-3.0 anchors

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra** | | | **Random Access** | | | **Low delay B** | | |
|  | G/Y | B/U | R/V | G/Y | B/U | R/V | G/Y | B/U | R/V |
| RGB, text & graphics with motion, 1080p & 720p | -2.3% | -3.7% | -3.5% | -3.7% | -5.6% | -5.4% | -4.0% | -5.6% | -5.5% |
| RGB, mixed content, 1440p & 1080p | -1.4% | -2.2% | -2.3% | -1.2% | -2.7% | -2.8% | -1.7% | -3.3% | -3.5% |
| RGB, Animation, 720p | 0.0% | 0.0% | 0.0% | 0.0% | -0.2% | -0.2% | -0.2% | -0.4% | -0.4% |
| RGB, camera captured, 1080p | 0.0% | 0.0% | 0.1% | -0.2% | -0.2% | -0.3% | 0.0% | 0.0% | 0.0% |
| YUV, text & graphics with motion, 1080p & 720p | -2.3% | -3.6% | -3.5% | -3.7% | -5.4% | -5.6% | -4.2% | -5.7% | -6.0% |
| YUV, mixed content, 1440p & 1080p | -1.4% | -2.4% | -2.5% | -1.5% | -3.4% | -3.5% | -2.1% | -4.5% | -5.1% |
| YUV, Animation, 720p | -0.2% | -0.2% | -0.3% | -0.2% | -0.4% | -0.1% | -0.2% | -0.5% | -0.3% |
| YUV, camera captured, 1080p | 0.1% | 0.1% | 0.1% | -0.2% | -0.2% | -0.1% | -0.1% | 0.0% | -0.1% |
| Enc Time[%] | 98% | | | 96% | | | 96% | | |
| Dec Time[%] | 92% | | | 90% | | | 94% | | |

Table 6. Average BD rate reduction for 420 lossy coding in CE-2 Test-1 platform compared with SCM-3.0 anchors

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra** | | | **Random Access** | | | **Low delay B** | | |
|  | G/Y | B/U | R/V | G/Y | B/U | R/V | G/Y | B/U | R/V |
| Text & graphics with motion, 720p | -4.6% | -5.0% | -5.1% | -3.1% | -4.0% | -3.8% | -2.3% | -3.0% | -3.7% |
| Mixed content, 480p | -1.2% | -1.4% | -1.7% | -0.7% | -1.4% | -1.6% | -0.2% | -0.4% | -0.7% |
| Animation, 768p | -0.9% | -1.6% | -1.8% | -0.8% | -2.6% | -2.4% | -0.6% | -1.0% | -1.9% |
| Average of all sequences | -2.9% | -3.2% | -3.4% | -1.9% | -3.0% | -2.9% | -1.3% | -1.9% | -2.5% |
| Enc Time[%] | 91% | | | 96% | | | 95% | | |
| Dec Time[%] | 95% | | | 90% | | | 93% | | |

Table 7. Average BD rate reduction for 444 lossless coding in CE-2 Test-1 platform compared with SCM-3.0 anchors

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| a | **All Intra** | | | | **Random Access** | | | | **Low Delay B** | | | |
|  | Bit-rate change (Total) | Bit-rate change (Avg.) | Bit-rate change (Min) | Bit-rate change (Max) | Bit-rate change (Total) | Bit-rate change (Avg.) | Bit-rate change (Min) | Bit-rate change (Max) | Bit-rate change (Total) | Bit-rate change (Avg.) | Bit-rate change (Min) | Bit-rate change (Max) |
|  |
| RGB, text & graphics with motion, 1080p & 720p | -0.3% | -0.6% | -1.9% | 0.3% | -0.8% | -1.3% | -3.4% | -0.2% | -0.7% | -1.5% | -5.6% | -0.2% |
| RGB, mixed content, 1440p & 1080p | -1.0% | -0.9% | -2.1% | 0.0% | -0.3% | -0.3% | -0.6% | 0.0% | -0.2% | -0.2% | -0.4% | 0.0% |
| RGB, Animation, 720p | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| RGB, camera captured, 1080p | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| YUV, text & graphics with motion, 1080p & 720p | 0.4% | 0.3% | -1.3% | 2.1% | -0.3% | -0.7% | -2.5% | 0.1% | -0.2% | -1.0% | -5.3% | 0.0% |
| YUV, mixed content, 1440p & 1080p | -0.7% | -0.6% | -1.8% | 0.2% | -0.2% | -0.2% | -0.5% | 0.0% | -0.1% | -0.2% | -0.3% | 0.0% |
| YUV, Animation, 720p | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| YUV, camera captured, 1080p | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Enc Time[%] | 90% | | | | 94% | | | | 95% | | | |
| Dec Time[%] | 95% | | | | 95% | | | | 99% | | | |

Table 8. Average BD rate reduction for 420 lossless coding in CE-2 Test-1 platform compared with SCM-3.0 anchors

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra** | | | | **Random Access** | | | | **Low Delay B** | | | |
|  | Bit-rate change (Total) | Bit-rate change (Average) | Bit-rate change (Min) | Bit-rate change (Max) | Bit-rate change (Total) | Bit-rate change (Average) | Bit-rate change (Min) | Bit-rate change (Max) | Bit-rate change (Total) | Bit-rate change (Average) | Bit-rate change (Min) | Bit-rate change (Max) |
|  |
| Text & graphics with motion, 720p | -2.5% | -2.5% | -3.8% | -1.2% | -0.7% | -0.9% | -1.3% | -0.5% | -0.3% | -0.5% | -0.7% | -0.2% |
| Mixed content, 480p | -0.1% | -0.1% | -0.1% | -0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Animation, 768p | 0.1% | 0.1% | 0.1% | 0.1% | -0.1% | -0.1% | -0.1% | -0.1% | -0.1% | -0.1% | -0.1% | -0.1% |
| Average of all sequences | -0.7% | -1.2% | -3.8% | 0.1% | -0.1% | -0.5% | -1.3% | 0.0% | -0.1% | -0.2% | -0.7% | 0.0% |
| Enc Time[%] | 69% | | | | 93% | | | | 94% | | | |
| Dec Time[%] | 99% | | | | 93% | | | | 97% | | | |

# Patent rights declaration(s)

**InterDigital Communications, Inc. 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).**

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