|  |  |
| --- | --- |
| **Joint Collaborative Team on Video Coding (JCT-VC)**  **of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29/WG 11**  22nd Meeting: Geneva, CH, 15–21 Oct. 2015 | Document: JCTVC-V0066 |

|  |  |  |  |
| --- | --- | --- | --- |
| *Title:* | **On constrained intra prediction for the unification framework of intra block copy** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Proposal | | |
| *Author(s) or Contact(s):* | Xiaoyu Xiu, Yan Ye Yuwen He 9710 Scranton Rd, #250 San Diego, CA 92121, USA | Tel: Email: | + 1-858-210-4830 [Xiaoyu.Xiu@InterDigital.com](mailto:Xiaoyu.Xiu@InterDigital.com)  [Yan.Ye@InterDigital.com](mailto:Yan.Ye@InterDigital.com)  [Yuwen.He@InterDigital.com](mailto:Yuwen.He@InterDigital.com) |
| *Source:* | InterDigital Communications Inc. | | |

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

# Abstract

This contribution proposes to modify the current design of constrained intra prediction (CIP) in HEVC screen content coding draft 4 by disallowing the samples of inter CUs, either predicted from temporal reference pictures or the current picture itself, to be used as references for intra prediction. It is asserted that the proposed method is more consistent with the unification framework of intra block copy (IBC) than the existing CIP solution in SCC draft 4, and that it improves coding performance when CIP is enabled.

Compared to SCM5.2 anchor, using the common test condition (CTC) with the CIP functionality being enabled, the proposed method provides average {G/Y, B/U, R/V} BD-rate savings of {2.0%, 2.1%, 2.1%} and {3.1%, 3.2%, 3.3%} for RA and LB configurations using full IBC search, and average {G/Y, B/U, R/V} BD-rate savings of {1.2%, 1.2%, 1.3%} and {1.8%, 1.9%, 1.9%} for RA and LB configurations using local IBC search.

Additional experiments are also conducted under gradual intra refreshing (IR) conditions for LB configuration, as outlined in JCTVC-O0352 and JCTVC-U0178. Experimental results show that the proposed method provides average {G/Y, B/U, R/V} BD-rate savings of {1.5%, 1.6%, 1.5%} and {0.3%, 0.4%, 0.4%} for CTU-column-based and slice-based IR testing cases, respectively, for full IBC search. When local IBC search is used, the corresponding {G/Y, B/U, R/V} BD-rate savings are {0.9%, 1.0%, 1.0%} and {0.2%, 0.3%, 0.3%} for CTU-column-based and slice-based IR, respectively.

# Proposal

In IBC unification framework of HEVC screen content draft 4 [1], IBC CUs are signalled as inter mode by adding the current picture (without in-loop filtering) into the reference picture list(s). However, it was found that when the CIP is enabled, IBC samples (i.e., samples predicted from the current picture) and normal inter samples (i.e., samples predicted from temporal reference pictures) are treated differently when being used as references for intra prediction. Specifically, when the CIP is enabled, intra prediction is allowed to use the samples of neighboring IBC CUs as reference while normal inter CUs are prevented from being used as reference for intra prediction. Additionally, in order to prevent temporal error propagation from IBC CUs to intra CUs, IBC prediction is not allowed to be predicted from normal inter CUs and the TMVP is disallowed when the reference picture is the current picture.

In this contribution, it is proposed to only allow the samples of intra CUs to be used as references for intra prediction when CIP is enabled. In other words, all the samples of inter CUs, either normal inter CUs that refer to temporal reference pictures or IBC CUs that refer to the current picture, are not allowed to be used to predict intra CUs. As it is disallowed to predict intra CUs from IBC CUs, errors due to temporal BV prediction could not propagate into intra samples. Therefore, TMVP can be enabled for IBC CUs in the proposed method. Additionally, the proposed CIP solution is only applied to P/B-slices that use at least one temporal reference picture. For P/B-slices that have reference picture list(s) containing only the current picture, the proposed CIP method still allows intra prediction to use reference samples from either intra predicted CUs or IBC predicted CUs. The asserted advantages of the proposed CIP method include the following:

1. The proposed method provides higher coding efficiency when CIP is enabled, because it improves the coding performance of IBC CUs by allowing inter samples in already coded areas of the current picture to be used for IBC prediction.
2. The proposed method is more consistent with the unification framework because it treats IBC CUs and inter CUs identically with regards to whether they could be used as references for intra prediction (that is, both are disallowed to be used in intra prediction) when the CIP is enabled.

It is also worth mentioning that previously a solution same to the proposed CIP method was proposed in [2] during the development of HEVC range extension (RExt).

# Simulation results

The proposed method is implemented based on SCM-5.2 and tested using the following settings:

* Setting one: the current common test condition [3] except that the CIP functionality is enabled, i.e., setting ConstrainedIntraPred to 1.
* Setting two (CTU-column-based intra refreshing): for LB configuration, pick one CTU column in one picture and force to code them using intra mode. Additionally, the intra CTU column moves from left to right along the picture decoding/display order [4].
* Setting three (slice-based intra refreshing): for LB configuration, pictures are divided evenly into 3 slices and each time one slice is refreshed using intra mode on a cyclic basis [4].

## Setting one

Table 1 BD-rate performance of the proposed method, compared to SCM-5.2 CIP solution on 444 sequences using full IBC search

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Random Access** | | |
|  | G/Y | B/U | R/V |
| RGB, text & graphics with motion, 1080p & 720p | -5.7% | -5.8% | -5.7% |
| RGB, mixed content, 1440p & 1080p | -2.6% | -2.7% | -2.8% |
| RGB, Animation, 720p | -0.1% | -0.2% | -0.2% |
| RGB, camera captured, 1080p | 0.0% | 0.0% | 0.0% |
| YUV, text & graphics with motion, 1080p & 720p | -5.1% | -5.1% | -5.1% |
| YUV, mixed content, 1440p & 1080p | -2.5% | -2.7% | -2.7% |
| YUV, Animation, 720p | -0.1% | -0.1% | -0.1% |
| YUV, camera captured, 1080p | -0.1% | -0.1% | -0.1% |
| Enc Time[%] | 98% | | |
| Dec Time[%] | 100% | | |
|  |  |  |  |
|  | **Low delay B** | | |
|  | G/Y | B/U | R/V |
| RGB, text & graphics with motion, 1080p & 720p | -7.4% | -7.6% | -7.6% |
| RGB, mixed content, 1440p & 1080p | -4.6% | -4.8% | -4.9% |
| RGB, Animation, 720p | -0.3% | -0.5% | -0.4% |
| RGB, camera captured, 1080p | 0.0% | -0.1% | -0.1% |
| YUV, text & graphics with motion, 1080p & 720p | -7.2% | -7.1% | -7.2% |
| YUV, mixed content, 1440p & 1080p | -4.7% | -5.1% | -5.0% |
| YUV, Animation, 720p | -0.2% | -0.5% | -0.7% |
| YUV, camera captured, 1080p | 0.0% | 0.0% | -0.3% |
| Enc Time[%] | 100% | | |
| Dec Time[%] | 97% | | |
|  |  |  |  |

## 

Table 2 BD-rate performance of the proposed method, compared to SCM-5.2 CIP solution on 444 sequences using local IBC search

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Random Access** | | |
|  | G/Y | B/U | R/V |
| RGB, text & graphics with motion, 1080p & 720p | -3.4% | -3.5% | -3.4% |
| RGB, mixed content, 1440p & 1080p | -1.4% | -1.5% | -1.5% |
| RGB, Animation, 720p | -0.1% | -0.1% | -0.2% |
| RGB, camera captured, 1080p | 0.0% | 0.0% | 0.0% |
| YUV, text & graphics with motion, 1080p & 720p | -3.1% | -3.1% | -3.1% |
| YUV, mixed content, 1440p & 1080p | -1.4% | -1.4% | -1.5% |
| YUV, Animation, 720p | -0.1% | -0.3% | -0.2% |
| YUV, camera captured, 1080p | 0.0% | 0.0% | 0.0% |
| Enc Time[%] | 100% | | |
| Dec Time[%] | 100% | | |
|  |  |  |  |
|  | **Low delay B** | | |
|  | G/Y | B/U | R/V |
| RGB, text & graphics with motion, 1080p & 720p | -4.5% | -4.6% | -4.6% |
| RGB, mixed content, 1440p & 1080p | -2.4% | -2.6% | -2.6% |
| RGB, Animation, 720p | -0.2% | -0.3% | -0.3% |
| RGB, camera captured, 1080p | -0.1% | 0.0% | 0.0% |
| YUV, text & graphics with motion, 1080p & 720p | -4.3% | -4.3% | -4.4% |
| YUV, mixed content, 1440p & 1080p | -2.6% | -2.6% | -2.6% |
| YUV, Animation, 720p | -0.3% | -0.6% | -0.3% |
| YUV, camera captured, 1080p | -0.1% | -0.1% | 0.0% |
| Enc Time[%] | 102% | | |
| Dec Time[%] | 99% | | |
|  |  |  |  |

Table 3 BD-rate performance of the proposed method, compared to SCM-5.2 CIP solution on 420 sequences

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Random Access** | | |
|  | G/Y | B/U | R/V |
| YUV, text & graphics with motion, 1080p & 720p | -6.7% | -6.9% | -7.0% |
| YUV, mixed content, 1440p & 1080p | -2.8% | -3.1% | -3.1% |
| YUV, Animation, 720p | -0.2% | -0.4% | -0.5% |
| Enc Time[%] | 97% | | |
| Dec Time[%] | 100% | | |
|  |  |  |  |
|  | **Low delay B** | | |
|  | G/Y | B/U | R/V |
| YUV, text & graphics with motion, 1080p & 720p | -8.7% | -9.0% | -9.1% |
| YUV, mixed content, 1440p & 1080p | -4.5% | -4.5% | -4.5% |
| YUV, Animation, 720p | -0.4% | -0.7% | -0.6% |
| Enc Time[%] | 100% | | |
| Dec Time[%] | 99% | | |

## Setting two

Table 4 BD-rate performance of the proposed method, compared to SCM-5.2 CIP solution on 444 sequences using full IBC search and CTU-column-based intra refreshing

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Low delay B** | | |
|  | G/Y | B/U | R/V |
| RGB, text & graphics with motion, 1080p & 720p | -3.6% | -3.7% | -3.7% |
| RGB, mixed content, 1440p & 1080p | -2.5% | -2.7% | -2.7% |
| RGB, Animation, 720p | -0.1% | -0.2% | -0.2% |
| RGB, camera captured, 1080p | 0.0% | 0.0% | 0.0% |
| YUV, text & graphics with motion, 1080p & 720p | -3.2% | -3.3% | -3.3% |
| YUV, mixed content, 1440p & 1080p | -2.4% | -2.5% | -2.5% |
| YUV, Animation, 720p | -0.3% | -0.4% | 0.0% |
| YUV, camera captured, 1080p | 0.0% | 0.1% | 0.1% |
| Enc Time[%] | 99% | | |
| Dec Time[%] | 99% | | |

Table 5 BD-rate performance of the proposed method, compared to SCM-5.2 CIP solution on 444 sequences using local IBC search and CTU-column-based intra refreshing

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Low delay B** | | |
|  | G/Y | B/U | R/V |
| RGB, text & graphics with motion, 1080p & 720p | -2.2% | -2.3% | -2.3% |
| RGB, mixed content, 1440p & 1080p | -1.3% | -1.4% | -1.4% |
| RGB, Animation, 720p | -0.1% | -0.2% | -0.2% |
| RGB, camera captured, 1080p | 0.0% | 0.0% | 0.0% |
| YUV, text & graphics with motion, 1080p & 720p | -2.0% | -2.2% | -2.0% |
| YUV, mixed content, 1440p & 1080p | -1.4% | -1.5% | -1.4% |
| YUV, Animation, 720p | -0.1% | -0.6% | -0.3% |
| YUV, camera captured, 1080p | 0.0% | -0.1% | 0.0% |
| Enc Time[%] | 105% | | |
| Dec Time[%] | 103% | | |

Table 6 BD-rate performance of the proposed method, compared to SCM-5.2 CIP solution on 420 sequences using CTU-column-based intra refreshing

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Low delay B** | | |
|  | G/Y | B/U | R/V |
| YUV, text & graphics with motion, 1080p & 720p | -4.6% | -4.6% | -4.7% |
| YUV, mixed content, 1440p & 1080p | -2.5% | -2.2% | -2.7% |
| YUV, Animation, 720p | -0.3% | -0.5% | -0.2% |
| Enc Time[%] | 98% | | |
| Dec Time[%] | 101% | | |

## Setting three

Table 7 BD-rate performance of the proposed method, compared to SCM-5.2 CIP solution on 444 sequences using full IBC search and slice-based intra refreshing

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Low delay B** | | |
|  | G/Y | B/U | R/V |
| RGB, text & graphics with motion, 1080p & 720p | -1.1% | -1.1% | -1.1% |
| RGB, mixed content, 1440p & 1080p | -0.4% | -0.4% | -0.4% |
| RGB, Animation, 720p | 0.0% | -0.1% | -0.1% |
| RGB, camera captured, 1080p | 0.0% | 0.0% | 0.0% |
| YUV, text & graphics with motion, 1080p & 720p | -0.9% | -1.0% | -1.0% |
| YUV, mixed content, 1440p & 1080p | -0.3% | -0.4% | -0.4% |
| YUV, Animation, 720p | -0.1% | -0.1% | 0.0% |
| YUV, camera captured, 1080p | 0.0% | 0.0% | 0.0% |
| Enc Time[%] | 102% | | |
| Dec Time[%] | 104% | | |
|  |  |  |  |

Table 8 BD-rate performance of the proposed method, compared to SCM-5.2 CIP solution on 444 sequences using local IBC search and slice-based intra refreshing

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Low delay B** | | |
|  | G/Y | B/U | R/V |
| RGB, text & graphics with motion, 1080p & 720p | -0.7% | -0.8% | -0.8% |
| RGB, mixed content, 1440p & 1080p | -0.2% | -0.2% | -0.2% |
| RGB, Animation, 720p | 0.0% | -0.1% | -0.1% |
| RGB, camera captured, 1080p | 0.0% | 0.0% | 0.0% |
| YUV, text & graphics with motion, 1080p & 720p | -0.6% | -0.7% | -0.7% |
| YUV, mixed content, 1440p & 1080p | -0.2% | -0.2% | -0.2% |
| YUV, Animation, 720p | -0.1% | -0.1% | -0.1% |
| YUV, camera captured, 1080p | 0.0% | 0.0% | 0.0% |
| Enc Time[%] | 105% | | |
| Dec Time[%] | 102% | | |

Table 9 BD-rate performance of the proposed method, compared to SCM-5.2 CIP solution on 420 sequences using slice-based intra refreshing

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Low delay B** | | |
|  | G/Y | B/U | R/V |
| YUV, text & graphics with motion, 1080p & 720p | -1.3% | -1.3% | -1.3% |
| YUV, mixed content, 1440p & 1080p | -0.3% | -0.4% | -0.4% |
| YUV, Animation, 720p | -0.1% | -0.1% | -0.2% |
| Enc Time[%] | 99% | | |
| Dec Time[%] | 101% | | |

# Proposed specification changes

##### 7.4.3.3.1 General picture parameter set RBSP semantics

**constrained\_intra\_pred\_flag** equal to 0 specifies that intra prediction allows usage of residual data and decoded samples of neighbouring coding blocks coded using either intra or inter prediction modes ~~with or without using a reference picture that is not the current picture~~. constrained\_intra\_pred\_flag equal to 1 specifies constrained intra prediction, in which case ~~the general~~ intra prediction process for slices that use at least one reference picture that is not the current picture only uses residual data and decoded samples from neighbouring coding blocks coded ~~without~~ using intra prediction mode ~~a reference picture that is not the current picture~~.

##### 8.4.4.2.1 General intra sample prediction

……

– Each sample p[ x ][ y ] is derived as follows:

* If one or more of the following conditions are true, the sample p[ x ][ y ] is marked as "not available for intra prediction":
  + The variable availableN is equal to FALSE.
  + CuPredMode[ xNbY ][ yNbY ] is not equal to MODE\_INTRA, DiffPicOrderCnt (aPic, CurrPic) is not equal to 0 for at least one picture aPic in RefPicList0 and RefPicList1 of the current slice and constrained\_intra\_pred\_flag is equal to 1.
* Otherwise, the sample p[ x ][ y ] is marked as "available for intra prediction" and the sample at the location ( xNbCmp, yNbCmp ) is assigned to p[ x ][ y ].
* ……

##### 8.5.3.2.8 Derivation process for temporal luma motion vector prediction

……

The variables mvLXCol and availableFlagLXCol are derived as follows:

* If slice\_temporal\_mvp\_enabled\_flag is equal to 0, both components of mvLXCol are set equal to 0 and availableFlagLXCol is set equal to 0.
* ~~Otherwise, if the reference picture is the current picture and constrained\_intra\_pred\_flag is equal to 1, both components of mvLXCol are set equal to 0 and availableFlagLXCol is set equal to 0.~~

……

# References

1. R. Joshi, S. Liu, G. J. Sullivan, J. Xu, Y. Ye, HEVC Screen Content Coding Draft Text 4, JCTVC-U1005, June 2015, Warsaw, Poland.
2. C. Pang, J. Chen, J. Sole, L. Guo, R. Joshi, M. Karczewicz, AhG5: Constrained intra prediction for intra block copying, JCTVC-O0155, October 2013, Geneva, Switzerland.
3. H. Yu, R. Cohen, K. Rapaka, J. Xu, Common Test Conditions for Screen Content Coding, JCTVC-U1015, June 2015, Warsaw, Poland.
4. X. Xiu, BoG report on constrained intra prediction for intra block copy unification, JCTVC-U0178, June 2015, Warsaw, Poland.
5. D. Flynn, C. Rosewarne, BoG report on range extensions topics, JCTVC-O0352, October 2013, Geneva, Switzerland.

# Patent rights declaration(s)

**InterDigital Communications Inc. may have current or pending patent rights 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).**