|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| |  |  | | --- | --- | | **Joint Collaborative Team on Video Coding (JCT-VC)**  **of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29/WG 11**  15th Meeting: Geneva, CH, 23 Oct. – 1 Nov. 2013 | Document: JCTVC-Oxxxx | | Document: JCTVC-O0037 |  |

|  |  |  |  |
| --- | --- | --- | --- |
| *Title:* | **RCE3: Summary report of HEVC Range Extensions Core Experiment 3 on Intra Prediction techniques** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Report | | |
| *Author(s) or Contact(s):* | Ankur Saxena  Do-Kyoung Kwon  Matteo Naccari  Chao Pang | Email: | [asaxena@sta.samsung.com](mailto:asaxena@sta.samsung.com)  [d-kwon@ti.com](mailto:d-kwon@ti.com)  [matteo.naccari@bbc.co.uk](mailto:matteo.naccari@bbc.co.uk)  [cpang@qti.qualcomm.com](mailto:cpang@qti.qualcomm.com) |
| *Source:* | CE coordinators | | |

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

# Introduction

This is a summary report on HEVC Range Extensions Core Experiment 3 on intra prediction techniques. The core experiment investigated sample adaptive prediction for various oblique modes, and a nearest neighbor interpolation technique which replaces bilinear interpolation for oblique intra prediction modes. Performance of the proposed methods as well as their combinations was evaluated for both lossy and lossless configurations based on the test conditions and sequences described in JCTVC-N1123 [1].

# Document List

## Subtest A

### CE contributions

* Tool A.1
  + JCTVC-O0080, RCE3: Results of Test A.1 on sample based intra prediction for lossless coding, J Zhu, W Zheng, K.Kazui(Fujitsu)
    - Cross-Check: JCTVC-O0050, RCE 3: A Cross-Check report of Tool A.1 (JCTVC-O0080) from Fujitsu, A. Saxena, F. Fernandes (Samsung)
    - Cross-Check: JCTVC-O0203, RCE 3: Cross-Check of Tool A.1 from Fujitsu Z. Ma, J. Ye, H. Yu (Huawei)
* Tool A.2
  + JCTVC-O0047, RCE 3: On sample adaptive intra prediction for oblique modes in lossless coding H. Chen, A. Saxena, F. Fernandes (Samsung)
  + JCTVC-O0048, RCE 3: On sample adaptive intra prediction for oblique modes in lossy coding, A. Saxena, H. Chen, F. Fernandes (Samsung)
    - Cross-check: JCTVC-O0204, RCE 3: Cross-check of Results of Experiment B.1 from Samsung, Z. Ma, J. Ye, H. Yu (Huawei)
    - Cross-check: JCTVC-O0081, RCE3: Cross-check of Test A.2.4, A.2.5, and B.1.2 from Samsung, J Zhu, W Zheng, K Kazui (Fujitsu)
    - Cross-check: JCTVC-O0278, RCE3: Crosscheck of JCTVC-O0047 on sample adaptive intra prediction for oblique modes in lossless coding, D.-K. Kwon (TI)
    - Cross-check: JCTVC-O0293, RCE3: Cross-check of Test A.2.5 (JCTVC-O0048) SAP for oblique modes in lossy coding, P. Lai, S. Liu (Mediatek)
* Tool A.3
  + JCTVC-O0049, RCE 3: Nearest-neighbor intra prediction for screen content video coding, H. Chen, A. Saxena, F. Fernandes (Samsung)
    - Cross-check: JCTVC-O0280, RCE3: Cross check of Test A.3 (Nearest-neighbor intra prediction for screen content video coding), M. Naccari, M. Mrak (BBC)

## Subtest B

### CE contributions

* Tool B.1
  + JCTVC-O0051, RCE 3: Combination of sample adaptive prediction and nearest neighbor prediction for oblique modes, A. Saxena, H. Chen, F. Fernandes (Samsung)
    - Cross-check: JCTVC-O0204, RCE 3: Cross-check of Results of Experiment B.1 from Samsung, Z. Ma, J. Ye, H. Yu (Huawei)
    - Cross-check: JCTVC-O0081, RCE3: Cross-check of Test A.2.4, A.2.5, and B.1.2 from Samsung, J Zhu, W Zheng, K Kazui (Fujitsu)

## Related non-CE contributions

* JCTVC-O0087, Non-RCE3: Unified lossless residual coding, Y. H. Tan, C. Yeo (I2R)
* JCTVC-O0178, Explicit signalling for intra RDPCM, J. Kang, R. Joshi, J. Sole, M. Karczewicz (Qualcomm)
* JCTVC-O181, Non-RCE3: Implicit derivation for adaptively turning filtering off in intra prediction, J. Kang, R. Joshi, J. Sole, M. Karczewicz (Qualcomm)

# High-Level Summary

Tools A.1 and A.2 in the RCE aim to extend SAP to strictly diagonal and oblique modes.

**Tool A.1** has 3 variants: one which reduces the total number of intra prediction modes to 13 instead of 35 in HEVC. It also extends SAP for 9 intra prediction modes, and results are provided for only lossless case. The other two variants in A.1 retain all the intra prediction modes in HEVC, and simply extend SAP for respectively for 9 and 5 intra prediction modes. Results for both lossless and lossy cases are provided.

For **Tool A.2**, there are 2 variants: one which extends SAP for 3 strictly diagonal modes, and the second which extends SAP for 7 modes. Lossless, and lossy results are provided for variant 1; and only lossless results are provided for variant 2. In addition, the results for both the variants in lossless case have been provided when the block size for applying SAP is restricted to 4x4 only.

**Tool A.3** is a nearest neighbor interpolation tool, and 2 variants are provided. Specifically, one variant is Rate-Distortion based, and the second one uses an implicit threshold criteria. For both these variants, results are provided for both lossless, and lossy scenario. In addition, it has been shown for both the variants that almost all gain can be retained when the tool is applied to block size 4x4 only.

Combination **Test B.1**, which is a combination of Test A.2 and A.3 shows that gains for tools A.2 and A.3 are additive; and decision of adoption can be made independently on them.

# Tested Methods

## Prediction techniques

A.1 (JCTVC-O0080: **Fujitsu, tested for both lossless and lossy)**

Proposes a modified version of the sample based intra prediction for lossless coding. Only 13 out of 35 possible intra prediction modes are used. DC and planar modes are unchanged. 11 angular modes use the nearest reference sample’s value in their direction as prediction value rather than using a filter, shown as Figure 1.



**Figure 1: Prediction for angular modes**

In this subtest, besides original proposal scheme, various variants are tested. Lossy coding in intra blocks where transform skip is selected is also tested. In lossy coding case, angular mode uses the nearest reference sample’s reconstructed value as prediction value.

**Test A.1.1**. 13 modes of intra prediction for lossless coding

**Test A.1.2**: Keep all modes of intra prediction in HEVC V1. The simplified SAP is applied for 9 angular modes (mode 2, 6, 10, 14, 18, 22, 26, 30, 34) for lossless coding.

**Test A.1.3**: Keep all modes of intra prediction in HEVC V1. The simplified SAP is applied for 5 angular modes (mode 2, 10, 18, 26, 34) for lossless coding.

**Test A.1.4**: Keep all modes of intra prediction in HEVC V1. The simplified SAP is applied for 9 angular modes (mode 2, 6, 10, 14, 18, 22, 26, 30, 34) for lossy coding.

**Test A.1.5**: Keep all modes of intra prediction in HEVC V1. The simplified SAP is applied for 5 angular modes (mode 2, 10, 18, 26, 34) for lossy coding.

**Test A.2 (**JCTVC-O0047**, JCTVC-O0048, Samsung, tested for both lossless and lossy)**

In this subtest, SAP is applied for strictly diagonal modes (modes 2, 18 and 34) for both lossless, and lossy settings (when cuTransformQuantBypass is selected).

Supplementary results are also provided for applying SAP additionally for 4 other pseudo-diagonal modes (modes 6, 14, 22 and 30).

Test A.2.1: SAP applied on 3 diagonal modes at all block sizes. Lossless.

Test A.2.2: SAP on 7 modes. Lossless. All block sizes.

Test A.2.3: SAP applied on 3 diagonal modes at block sizes 4x4. Lossless.

Test A.2.4: SAP on 7 modes. Lossless. Block sizes 4x4.

Test A.2.5: SAP applied on 3 diagonal modes. Lossy (when cuTransfQuantBypass is invoked.)

**Test A.3 (JCTVC-O0049, Samsung, tested for both lossless and lossy)**

In this test, nearest neighbor prediction is used instead of bilinear interpolation for intra prediction. Two different tests are performed:

Test A.3.1: A Rate-Distortion criteria is used to select between the nearest neighbor prediction, or retaining bilinear interpolation at the encoder. At all block sizes.

Test A.3.2: A threshold based pixel difference criteria is used to select between the nearest neighbor prediction, or retaining bilinear interpolation at the encoder. At all block sizes.

Test A.3.3: A Rate-Distortion criteria is used to select between the nearest neighbor prediction, or retaining bilinear interpolation at the encoder. Only at block sizes 4x4.

Test A.3.4: A threshold based pixel difference criteria is used to select between the nearest neighbor prediction, or retaining bilinear interpolation at the encoder. Only at block sizes 4x4.

***3.2 Combination Tests***

**Test B.1 (JCTVC-O0051, Samsung, both lossless and lossy):** In this combination test, methods in tests A.2 and A.3 described above are jointly testes for both lossless and lossy settings. Results are found to be additive.

# Summary of Results

The proposed methods were implemented on top of HM12.0+Rext4.1 and simulated under the RCE3 common test conditions [1]. For lossless configuration, All Intra, RA, and LD-B results are provided. For lossy configurations, results are reported for the main-tier (QP = 22, 27, 32, 27) and high-tier (QP = 17, 22, 27, 32); and for intra, additionally the Super-High tier (QP = 12, 17, 22, 27).

## Subtest A (A.1 and A.2)

### Lossless (Positive numbers are bit-rate savings)















### Lossy (Negative numbers are BD-Rate gains)



Note: Encoding/Decoding times in Table A.1.5 are inaccurate.





## Subtest A (A.3)

### Lossless (Positive numbers are bit-rate savings)









### Lossy (Negative numbers are BD-Rate gains)









## Subtest B

### Combination Test B.1 = (A.2+A.3)

### Lossless (Positive numbers are bit-rate savings)





### Lossy (Negative numbers are BD-Rate gains)





# Recommendations

It is recommended to discuss all the tools in the RCE 3, and adopt the promising one(s).

# References

1. A. Saxena, D. Kwon, M. Naccari and C. Pang, “HEVC Range Extensions Core Experiment 3 (RCE3): Intra Prediction techniques,” JCTVC-N1123, Vienna, Austria, July 2013.