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**ISO/IEC JTC 1/SC 29/WG 7 MPEG 3D Graphics Coding**

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| --- | --- |
| **Title** | **V-PCC Best Encoding Practices** |
| **Source** | **WG 7, MPEG 3D Graphics Coding** |
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**[V-PCC] V-PCC Best Encoding Practices**

1. **Introduction**

This document summarizes best encoding practices for V-PCC encoder tools and corresponding video encoder tools.

1. **Coding performance optimization**
   1. ***General***

The operation of the V-PCC specification assumes that dynamic point clouds can be compressed with an arbitrary video codec. This document summarizes the video encoders and video encoder tools and their contribution to the compression efficiency of the dynamic point cloud coding. The tests are held under CTC [1] for the V-PCC.

* 1. ***V-PCC internal encoder tools***

Several encoder-only tools are used to improve the coding efficiency of the dynamic point cloud test model TMC2.

Important factors are packing, patch segmentation, geometry and attribute smoothing, unoccupied samples padding, external tools such as occupancy-based rate-distortion optimization and 3D-assisted motion estimation.

* + 1. ***V-PCC Assisted 3D Motion Estimation compared to Search Range Extension***

This section provides simulation results for search range compared to assisted 3D motion estimation.

**Table 1 Experimental results under the C2 RA condition with 32 frames when an anchor is 3DME off, and the test is 3DME on. (Search range 64 for both)**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **C2\_ra** | **lossy geometry, lossy attributes [inter, random access]** | | | | | | | | | |
| **Geom. BD‑TotGeomRate [%]** | | **End-to-End BD‑AttrRate [%]** | | | **Geom. BD‑TotalRate [%]** | | **End-to-End BD‑TotalRate [%]** | | |
| **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** | **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** |
| loot | 0.2 | 0.3 | 0.1 | 4.6 | -1.6 | 0.2 | 0.3 | 0.2 | 2.9 | -0.8 |
| redandblack | -0.2 | -0.3 | -4.5 | -6.0 | -4.5 | -1.2 | -1.4 | -2.3 | -3.3 | -2.3 |
| soldier | -2.9 | -2.9 | -16.1 | -22.7 | -26.3 | -6.0 | -6.2 | -9.3 | -14.3 | -16.7 |
| queen | -0.5 | -0.6 | -0.4 | -1.5 | 0.2 | -0.5 | -0.6 | -0.5 | -0.9 | -0.1 |
| longdress | -0.3 | -0.2 | -2.2 | -3.1 | -2.5 | -1.3 | -1.1 | -1.4 | -2.0 | -1.6 |
| **Average** | -0.7 | -0.8 | -4.6 | -5.8 | -6.9 | -1.8 | -1.8 | -2.7 | -3.5 | -4.3 |
| Avg. Enc Time [%] | 100% | | | | | | | | | |
| Avg. Dec Time [%] | 100% | | | | | | | | | |

**Table 2 Experimental results under the C2 RA condition with 32 frames when search range of anchor is set to 64 and test is set to 384. (3DME off for both)**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **C2\_ra** | **lossy geometry, lossy attributes [inter, random access]** | | | | | | | | | |
| **Geom. BD‑TotGeomRate [%]** | | **End-to-End BD‑AttrRate [%]** | | | **Geom. BD‑TotalRate [%]** | | **End-to-End BD‑TotalRate [%]** | | |
| **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** | **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** |
| loot | 0.4 | 0.4 | 0.0 | 4.4 | -0.2 | 0.3 | 0.4 | 0.2 | 3.1 | 0.2 |
| redandblack | 0.1 | -0.1 | -4.1 | -5.1 | -3.8 | -0.8 | -1.1 | -2.0 | -2.7 | -1.8 |
| soldier | -2.6 | -2.7 | -15.4 | -22.0 | -24.7 | -5.7 | -5.8 | -8.8 | -13.6 | -15.7 |
| queen | 0.1 | -0.1 | -1.7 | -1.7 | 0.3 | -0.1 | -0.2 | -1.0 | -0.8 | 0.3 |
| longdress | -0.1 | 0.0 | -2.5 | -3.5 | -2.8 | -1.4 | -1.2 | -1.5 | -2.1 | -1.7 |
| **Average** | -0.4 | -0.5 | -4.7 | -5.6 | -6.3 | -1.5 | -1.6 | -2.6 | -3.2 | -3.7 |
| Avg. Enc Time [%] | 106% | | | | | | | | | |
| Avg. Dec Time [%] | 100% | | | | | | | | | |

**Table 3 Experimental results under the C2 RA condition with 32 frames when search range of anchor is set to 64 and test is set to 32. (3DME on for both)**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **lossy geometry, lossy attributes [inter, random access]** | | | | | | | | | |
| **Geom. BD‑TotGeomRate [%]** | | **End-to-End BD‑AttrRate [%]** | | | **Geom. BD‑TotalRate [%]** | | **End-to-End BD‑TotalRate [%]** | | |
| **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** | **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** |
| loot | -0.2 | -0.2 | 0.0 | 0.6 | 1.6 | -0.3 | -0.2 | 0.0 | 0.4 | 1.1 |
| redandblack | 0.0 | 0.0 | 0.3 | 0.5 | -0.1 | 0.1 | 0.1 | 0.1 | 0.2 | -0.1 |
| soldier | -0.2 | -0.2 | 0.3 | 0.3 | -1.2 | -0.2 | 0.0 | 0.1 | -0.1 | -0.9 |
| queen | 0.1 | 0.0 | -0.3 | -1.5 | -2.0 | 0.0 | -0.2 | -0.1 | -0.9 | -1.2 |
| longdress | -0.2 | -0.1 | 0.3 | 0.4 | 0.2 | 0.0 | 0.1 | 0.1 | 0.2 | 0.0 |
| **Average** | -0.1 | -0.1 | 0.1 | 0.1 | -0.3 | -0.1 | -0.1 | 0.0 | 0.0 | -0.2 |

Table 4 Experimental results under the C2 RA condition with 32 frames when search range of anchor is set to 64 and test is set to 384. (3DME on for both)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **lossy geometry, lossy attributes [inter, random access]** | | | | | | | | | |
| **Geom. BD‑TotGeomRate [%]** | | **End-to-End BD‑AttrRate [%]** | | | **Geom. BD‑TotalRate [%]** | | **End-to-End BD‑TotalRate [%]** | | |
| **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** | **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** |
| loot | 0.2 | 0.1 | 0.1 | 1.0 | 5.6 | 0.3 | 0.1 | 0.1 | 0.6 | 3.5 |
| redandblack | 0.2 | 0.2 | -0.3 | 0.7 | 0.0 | 0.1 | 0.1 | 0.0 | 0.6 | 0.2 |
| soldier | -0.4 | -0.3 | -1.0 | -1.4 | -3.0 | -0.8 | -0.5 | -0.5 | -0.7 | -1.7 |
| queen | 0.1 | 0.1 | -0.4 | 1.1 | -1.0 | -0.1 | 0.0 | 0.0 | 0.7 | -0.4 |
| longdress | 0.2 | 0.2 | -0.7 | -0.9 | -0.4 | -0.2 | -0.2 | -0.3 | -0.5 | -0.1 |
| **Average** | 0.1 | 0.1 | -0.5 | 0.1 | 0.2 | -0.2 | -0.1 | -0.1 | 0.1 | 0.3 |

* 1. ***V-PCC external encoder tools***

Considering the specifics of video projection creation in the TMC2 and V-PCC can influence the dynamic point cloud content compression.

* + 1. ***V-PCC external encoder tools***

The tool on/off experimental results vs. VTM anchor (embedded in the VPCC pipeline) are provided for the following tools:

* Deblocking filter: On
* GOP-based temporal filter: On
* Dual-tree: On
* LMChroma (Cross-component linear model, CCLM) : On
* Intra block copy: Off for natural images and ON for screen contents

Table **5 Experimental results under the C2 RA condition with 32 frames when the deblocking filter is Off for geometry**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **lossy geometry, lossy attributes [inter, random access]** | | | | | | | | | |
| **Geom. BD‑TotGeomRate [%]** | | **End-to-End BD‑AttrRate [%]** | | | **Geom. BD‑TotalRate [%]** | | **End-to-End BD‑TotalRate [%]** | | |
| **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** | **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** |
| loot | -2.6 | -3.2 | -0.4 | -4.4 | 2.7 | -1.1 | -1.8 | -3.0 | -5.2 | -1.0 |
| redandblack | -0.8 | -1.4 | -0.5 | -1.0 | -0.3 | 0.0 | -0.8 | -1.2 | -1.6 | -1.1 |
| soldier | -3.6 | -4.0 | -0.9 | 0.9 | -0.2 | -2.3 | -2.8 | -2.9 | -1.9 | -2.6 |
| queen | -3.7 | -4.2 | -0.5 | -0.9 | -4.2 | -2.1 | -2.8 | -2.6 | -3.1 | -5.0 |
| longdress | -0.9 | -1.4 | 0.3 | 0.1 | 0.0 | 1.1 | 0.1 | -0.5 | -0.7 | -0.8 |
| **Average** | -2.3 | -2.9 | -0.4 | -1.1 | -0.4 | -0.9 | -1.6 | -2.1 | -2.5 | -2.1 |

*Table* ***6 Experimental results under the C2 RA condition with 32 frames when the deblocking filter is Off for attribute***

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **lossy geometry, lossy attributes [inter, random access]** | | | | | | | | | |
| **Geom. BD‑TotGeomRate [%]** | | **End-to-End BD‑AttrRate [%]** | | | **Geom. BD‑TotalRate [%]** | | **End-to-End BD‑TotalRate [%]** | | |
| **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** | **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** |
| loot | 0.0 | 0.0 | 1.7 | 3.5 | 6.2 | 0.2 | 0.2 | 0.8 | 1.9 | 3.5 |
| redandblack | 0.0 | 0.0 | 1.5 | 2.3 | 1.4 | 0.2 | 0.2 | 0.8 | 1.3 | 0.8 |
| soldier | 0.0 | 0.0 | 0.4 | 3.3 | 1.8 | 0.1 | 0.1 | 0.1 | 2.0 | 0.9 |
| queen | 0.0 | 0.0 | 1.0 | 7.4 | 4.3 | 0.2 | 0.2 | 0.4 | 4.2 | 2.4 |
| longdress | 0.0 | 0.0 | 1.1 | 1.7 | 1.5 | 0.3 | 0.3 | 0.7 | 1.1 | 0.9 |
| **Average** | 0.0 | 0.0 | 1.1 | 3.6 | 3.1 | 0.2 | 0.2 | 0.6 | 2.1 | 1.7 |

Table **7 Experimental results under the C2 RA condition with 32 frames when GOP-based temporal filter is Off for geometry**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **lossy geometry, lossy attributes [inter, random access]** | | | | | | | | | |
| **Geom. BD‑TotGeomRate [%]** | | **End-to-End BD‑AttrRate [%]** | | | **Geom. BD‑TotalRate [%]** | | **End-to-End BD‑TotalRate [%]** | | |
| **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** | **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** |
| loot | -3.7 | -4.1 | -0.3 | -2.0 | 3.9 | -3.6 | -4.2 | -1.8 | -2.5 | 0.5 |
| redandblack | -9.5 | -9.5 | -1.5 | -0.1 | -1.5 | -11.1 | -11.1 | -2.8 | -1.9 | -2.9 |
| soldier | -4.8 | -4.8 | -1.3 | -1.4 | -2.1 | -5.8 | -5.8 | -1.8 | -1.9 | -2.5 |
| queen | -3.8 | -3.5 | -3.4 | -1.1 | -3.8 | -5.3 | -4.9 | -2.6 | -1.2 | -2.8 |
| longdress | -9.4 | -9.7 | -2.8 | -0.1 | -0.7 | -13.8 | -14.6 | -3.2 | -1.4 | -1.8 |
| **Average** | -6.3 | -6.3 | -1.9 | -1.0 | -0.8 | -7.9 | -8.1 | -2.4 | -1.8 | -1.9 |

**Table 8 Experimental results under the C2 RA condition with 32 frames when a temporal filter is Off for attribute**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **lossy geometry, lossy attributes [inter, random access]** | | | | | | | | | |
| **Geom. BD‑TotGeomRate [%]** | | **End-to-End BD‑AttrRate [%]** | | | **Geom. BD‑TotalRate [%]** | | **End-to-End BD‑TotalRate [%]** | | |
| **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** | **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** |
| loot | 0.0 | 0.0 | 2.5 | 1.5 | 3.1 | 1.5 | 1.8 | 0.4 | 0.0 | 1.0 |
| redandblack | 0.0 | 0.0 | -0.5 | -6.9 | 1.8 | 1.2 | 1.5 | -1.2 | -5.5 | 0.3 |
| soldier | 0.0 | 0.0 | 2.2 | 1.8 | 0.2 | 1.7 | 2.3 | 0.3 | -0.3 | -1.3 |
| queen | 0.0 | 0.0 | 2.1 | 1.7 | 0.3 | 1.6 | 1.9 | 0.6 | -0.1 | -0.7 |
| longdress | 0.0 | 0.0 | 3.8 | 3.5 | 4.1 | 3.5 | 3.9 | 2.0 | 1.7 | 2.1 |
| **Average** | 0.0 | 0.0 | 2.0 | 0.3 | 1.9 | 1.9 | 2.3 | 0.4 | -0.8 | 0.3 |

**Table 9 Experimental results under the C2 RA condition with 32 frames when dual-tree Off is for geometry**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **lossy geometry, lossy attributes [inter, random access]** | | | | | | | | | |
| **Geom. BD‑TotGeomRate [%]** | | **End-to-End BD‑AttrRate [%]** | | | **Geom. BD‑TotalRate [%]** | | **End-to-End BD‑TotalRate [%]** | | |
| **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** | **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** |
| loot | 0.0 | 0.0 | -0.5 | -3.5 | 0.2 | 0.1 | 0.0 | -0.4 | -1.9 | 0.0 |
| redandblack | -0.1 | 0.1 | -0.2 | 0.0 | 0.0 | -0.2 | 0.1 | -0.1 | -0.1 | 0.0 |
| soldier | -0.7 | -0.5 | -0.5 | 0.0 | -1.0 | -0.9 | -0.5 | -0.4 | -0.2 | -0.9 |
| queen | 0.2 | 0.1 | -1.1 | 0.4 | -0.1 | 0.2 | 0.2 | -0.5 | 0.1 | 0.2 |
| longdress | -0.1 | -0.1 | 0.0 | -0.6 | -0.4 | -0.1 | -0.2 | 0.0 | -0.4 | -0.3 |
| **Average** | -0.1 | -0.1 | -0.4 | -0.7 | -0.2 | -0.2 | -0.1 | -0.3 | -0.5 | -0.2 |

**Table 10 Experimental results under the C2 RA condition with 32 frames when dual-tree is Off for attribute**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **lossy geometry, lossy attributes [inter, random access]** | | | | | | | | | |
| **Geom. BD‑TotGeomRate [%]** | | **End-to-End BD‑AttrRate [%]** | | | **Geom. BD‑TotalRate [%]** | | **End-to-End BD‑TotalRate [%]** | | |
| **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** | **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** |
| loot | 0.0 | 0.0 | 0.4 | 17.0 | 12.6 | 0.1 | 0.1 | 0.1 | 10.5 | 7.5 |
| redandblack | 0.0 | 0.0 | -0.1 | 1.3 | -0.6 | 0.1 | 0.1 | -0.1 | 0.8 | -0.4 |
| soldier | 0.0 | 0.0 | 0.3 | 35.7 | 39.1 | 0.1 | 0.1 | 0.1 | 21.0 | 23.1 |
| queen | 0.0 | 0.0 | 0.2 | 7.5 | 3.2 | -0.1 | -0.1 | 0.2 | 5.0 | 2.4 |
| longdress | 0.0 | 0.0 | 0.2 | 0.7 | 1.2 | 0.1 | 0.1 | 0.1 | 0.5 | 0.8 |
| **Average** | 0.0 | 0.0 | 0.2 | 12.4 | 11.1 | 0.1 | 0.1 | 0.1 | 7.5 | 6.7 |

**Table 11 Experimental results under the C2 RA condition with 32 frames when the cross-component linear model (LMChroma) is Off for geometry**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **lossy geometry, lossy attributes [inter, random access]** | | | | | | | | | |
| **Geom. BD‑TotGeomRate [%]** | | **End-to-End BD‑AttrRate [%]** | | | **Geom. BD‑TotalRate [%]** | | **End-to-End BD‑TotalRate [%]** | | |
| **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** | **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** |
| loot | -0.5 | -0.4 | -0.2 | -4.6 | 0.8 | -0.5 | -0.4 | -0.3 | -2.9 | 0.1 |
| redandblack | -0.3 | -0.3 | 0.0 | 0.4 | -0.1 | -0.3 | -0.2 | -0.1 | 0.1 | -0.2 |
| soldier | -0.6 | -0.4 | -0.4 | -1.6 | -2.3 | -0.6 | -0.3 | -0.4 | -1.3 | -1.5 |
| queen | -0.4 | -0.4 | -0.4 | 0.8 | -1.9 | -0.4 | -0.4 | -0.3 | 0.3 | -1.2 |
| longdress | -0.5 | -0.4 | 0.1 | 0.0 | 0.1 | -0.4 | -0.2 | -0.1 | -0.2 | -0.1 |
| **Average** | -0.4 | -0.4 | -0.2 | -1.0 | -0.7 | -0.4 | -0.3 | -0.2 | -0.8 | -0.6 |

**Table 12 Experimental results under the C2 RA condition with 32 frames when the cross-component linear model (LMChroma) is Off for attribute**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **lossy geometry, lossy attributes [inter, random access]** | | | | | | | | | |
| **Geom. BD‑TotGeomRate [%]** | | **End-to-End BD‑AttrRate [%]** | | | **Geom. BD‑TotalRate [%]** | | **End-to-End BD‑TotalRate [%]** | | |
| **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** | **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** |
| loot | 0.0 | 0.0 | 0.3 | 15.9 | 13.2 | 0.0 | 0.0 | 0.1 | 10.0 | 7.8 |
| redandblack | 0.0 | 0.0 | 1.6 | 15.7 | 2.7 | 0.5 | 0.5 | 0.6 | 9.4 | 1.3 |
| soldier | 0.0 | 0.0 | -0.4 | 8.1 | 13.3 | 0.0 | 0.0 | -0.3 | 5.4 | 8.4 |
| queen | 0.0 | 0.0 | 0.4 | 25.4 | 18.4 | 0.2 | 0.2 | 0.2 | 15.8 | 11.4 |
| longdress | 0.0 | 0.0 | 0.5 | 11.4 | 8.4 | 0.3 | 0.3 | 0.4 | 8.0 | 5.9 |
| **Average** | 0.0 | 0.0 | 0.5 | 15.3 | 11.2 | 0.2 | 0.2 | 0.2 | 9.7 | 7.0 |

**Table 13 Experimental results under the C2 RA condition with 32 frames when intra block copy is On for geometry**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **lossy geometry, lossy attributes [inter, random access]** | | | | | | | | | |
| **Geom. BD‑TotGeomRate [%]** | | **End-to-End BD‑AttrRate [%]** | | | **Geom. BD‑TotalRate [%]** | | **End-to-End BD‑TotalRate [%]** | | |
| **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** | **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** |
| loot | 0.1 | -0.3 | -0.2 | -0.8 | 0.1 | 0.2 | -0.3 | -0.3 | -0.6 | -0.1 |
| redandblack | -0.3 | -0.3 | 0.2 | -0.7 | 0.1 | -0.3 | -0.3 | 0.0 | -0.7 | -0.1 |
| soldier | -0.2 | -0.1 | -0.4 | 0.5 | 0.9 | -0.4 | -0.2 | -0.2 | 0.5 | 0.6 |
| queen | 0.0 | -0.1 | -0.7 | 1.8 | -0.3 | 0.1 | 0.1 | -0.5 | 1.0 | -0.2 |
| longdress | -0.6 | -0.7 | -0.1 | 0.5 | 0.0 | -0.2 | -0.3 | -0.3 | 0.1 | -0.3 |
| **Average** | -0.2 | -0.3 | -0.3 | 0.3 | 0.2 | -0.1 | -0.2 | -0.3 | 0.1 | 0.0 |

**Table 14 Experimental results under the C2 RA condition with 32 frames when intra block copy is On for attribute**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **lossy geometry, lossy attributes [inter, random access]** | | | | | | | | | |
| **Geom. BD‑TotGeomRate [%]** | | **End-to-End BD‑AttrRate [%]** | | | **Geom. BD‑TotalRate [%]** | | **End-to-End BD‑TotalRate [%]** | | |
| **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** | **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** |
| loot | 0.0 | 0.0 | -0.4 | -2.2 | 0.8 | -0.1 | -0.1 | -0.1 | -1.0 | 0.6 |
| redandblack | 0.0 | 0.0 | 0.2 | -0.5 | 0.4 | 0.0 | 0.0 | 0.1 | -0.4 | 0.3 |
| soldier | 0.0 | 0.0 | -0.2 | -1.2 | -3.1 | -0.1 | 0.0 | -0.1 | -0.9 | -2.2 |
| queen | 0.0 | 0.0 | 0.3 | 1.5 | -1.1 | -0.1 | -0.1 | 0.3 | 0.8 | -0.6 |
| longdress | 0.0 | 0.0 | 0.3 | 0.6 | 0.4 | 0.0 | 0.0 | 0.2 | 0.3 | 0.2 |
| **Average** | 0.0 | 0.0 | 0.0 | -0.4 | -0.5 | -0.1 | 0.0 | 0.1 | -0.2 | -0.3 |

***Table 15 Experimental results under the C2 RA condition with 32 frames when deblocking filter and GOP-based temporal filter are Off for geometry***

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **lossy geometry, lossy attributes [inter, random access]** | | | | | | | | | |
| **Geom. BD‑TotGeomRate [%]** | | **End-to-End BD‑AttrRate [%]** | | | **Geom. BD‑TotalRate [%]** | | **End-to-End BD‑TotalRate [%]** | | |
| **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** | **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** |
| loot | -6.4 | -7.4 | -0.2 | -4.8 | -0.5 | -4.7 | -6.0 | -4.5 | -7.0 | -4.7 |
| redandblack | -10.1 | -11.0 | -1.9 | -0.2 | -1.8 | -10.8 | -12.1 | -4.1 | -3.0 | -4.1 |
| soldier | -8.6 | -8.8 | -2.1 | -3.1 | -3.7 | -8.0 | -8.4 | -4.8 | -5.5 | -6.0 |
| queen | -7.5 | -8.2 | -3.7 | -2.6 | -5.4 | -7.1 | -7.9 | -5.4 | -4.4 | -6.3 |
| longdress | -10.2 | -11.3 | -3.1 | -0.7 | -1.1 | -12.5 | -14.8 | -4.2 | -2.6 | -2.8 |
| **Average** | -8.5 | -9.3 | -2.2 | -2.3 | -2.5 | -8.6 | -9.9 | -4.6 | -4.5 | -4.8 |

***Table 16 Experimental results under the C2 RA condition with 32 frames when deblocking filter, GOP-based temporal filter, dual-tree, and cross-component linear model are turned off, and intra block copy is turned on for geometry.***

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **lossy geometry, lossy attributes [inter, random access]** | | | | | | | | | |
| **Geom. BD‑TotGeomRate [%]** | | **End-to-End BD‑AttrRate [%]** | | | **Geom. BD‑TotalRate [%]** | | **End-to-End BD‑TotalRate [%]** | | |
| **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** | **D1** | **D2** | **Luma** | **Chroma Cb** | **Chroma Cr** |
| loot | -5.5 | -6.5 | -0.1 | 1.3 | 4.8 | -3.9 | -5.3 | -4.0 | -3.0 | -1.3 |
| redandblack | -10.5 | -11.5 | -2.0 | 0.5 | -1.7 | -11.2 | -12.4 | -4.4 | -2.9 | -4.3 |
| soldier | -8.0 | -8.4 | -2.3 | -1.3 | -1.1 | -7.3 | -7.9 | -4.8 | -4.0 | -3.9 |
| queen | -8.4 | -8.6 | -4.5 | -0.6 | -6.2 | -8.2 | -8.3 | -6.0 | -3.6 | -7.0 |
| longdress | -10.9 | -11.8 | -3.1 | -0.5 | -1.1 | -13.2 | -15.1 | -4.4 | -2.7 | -3.1 |
| **Average** | -8.7 | -9.4 | -2.4 | -0.1 | -1.1 | -8.8 | -9.8 | -4.7 | -3.2 | -3.9 |
| Avg. Enc Time [%] | 100% | | | | | | | | | |
| Avg. Dec Time [%] | 97% | | | | | | | | | |

1. **References**

[1] Common Test Conditions for V-PCC, ISO/IEC JTC1/SC29 WG7 Doc. N00038, Online, October 2020.

[2] [V-PCC] Performance analysis according to 3DME and motion search range in V-PCC software with VVC, ISO/IEC JTC1/SC29 WG7 Doc. M58120, Online, October 2021.

[3] [V-PCC] Evaluation of coding performance of VVC according to coding tools in V-PCC software, ISO/IEC JTC1/SC29 WG7 Doc. M58121, Online, October 2021.