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**INTERNATIONAL ORGANISATION FOR STANDARDISATION**
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**CODING OF MOVING PICTURES AND AUDIO**

**ISO/IEC JTC 1/SC 29/WG 11 N19086**
**Brussels, BE – January 2020**

*Source:* 3DG
*Title:* G-PCC TMC13v9 performance evaluation and anchor results


## Abstract

This document provides the reference anchor results for experiments on point cloud compression for dynamically acquired content (category three) and high density content (category one) using the N19084 common test conditions [1].


## Summary

This report contains the following:

| | |
|---|---|
| report_*.txt | verification report of all data points |
| pcc–$B__vs__$A.xlsm | results reporting $B against $A |

Bitstreams and results were generated on a heterogeneous 64bit linux cluster using revision release-v9.0 of TMC13 built with gcc-5.3.1:

```
CMAKE_BUILD_TYPE:STRING=Release
CMAKE_CXX_FLAGS:STRING=-g -O3
CMAKE_CXX_FLAGS_RELEASE:STRING=-O3 -DNDEBUG
```

All distortion are measured using pc_error version release-0.13.4. Due to the nature of the cluster environment, reported run time changes are approximate only.

Subsequent to verification, the tag "release-v9.0" is available from http://mpegx.int-evry.fr/software/MPEG/PCC/TM/mpeg-pcc-tmc13. Further software documentation and usage description is available [2, 3].

## Anchor results according to common test conditions

Anchor results using the following common test conditions of N19084 are reported in the enclosed reporting sheets[1][2]:

- C1: (near) lossless geometry, lossy attributes [all intra],
- C2: lossy geometry, lossy attributes [all intra],
- CW: (near) lossless geometry, lossless attributes [all intra],
- CX: (near) lossless geometry, near lossless attributes [all intra],

NOTE — TMC13 is currently an intra only codec supporting random access.

[1] pcc-tmc13-tmc13v9.0_octree_raht__vs__tmc13v9.0_octree_predlift.xlsm
[2] pcc-tmc13-tmc13v9.0_trisoup_raht__vs__tmc13v9.0_trisoup_predlift.xlsm

## Summary analysis of v9.0 against v8.0 results

Compression results comparing v9.0 against v8.0 on test sequences from categories one and three using both the lod-based lifting/predicting transforms and RAHT are provided with this report[3][4][5][6] and summarised in tables 1 to 4. The presented summary data are computed using a modified v9.0 configuration to enable a fair comparison to v8.0. The modification excludes cat1-B sequences from conditions C1 and CY, and disables attribute coding for cat1-B sequences in conditions C2 and CW.

Table 1 – Summary performance of octree geometry and predlift attribute coding using release v9.0 relative to v8.0 results

| | | BPP Ratio [%] | | | BD-Rate [Δ%] | | | | | | Avg. of ratio maxrssk [%] | | Ratio of avg. runtime [%] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Condition | Class | Geometry | Colour | Refl | D1 | D2 | Y | Cb | Cr | R | Encoder | Decoder | Encoder | Decoder |
| C1_ai | cat1-A | | | | | | 1.3 | 2.8 | 3.5 | | 101 | 103 | 124 | 103 |
| C1_ai | cat3-fused | | | | | | 0.2 | 0.8 | 0.7 | 0.2 | 103 | 102 | 123 | 100 |
| C1_ai | cat3-frame | | | | | | | | | 0.0 | 98 | 99 | 158 | 127 |
| C1_ai | overall | | | | | | 1.1 | 2.5 | 3.2 | 0.1 | 100 | 102 | 130 | 108 |
| C2_ai | cat1-A | | | | −1.0 | −0.9 | −3.2 | −4.2 | −3.0 | | 90 | 100 | 96 | 72 |
| C2_ai | cat1-B | | | | −2.4 | −2.4 | | | | | 100 | 102 | 92 | 101 |
| C2_ai | cat3-fused | | | | 0.1 | 0.1 | −0.1 | 1.2 | 1.3 | −0.0 | 96 | 107 | 105 | 106 |
| C2_ai | cat3-frame | | | | −4.5 | −4.4 | | | | 0.7 | 97 | 101 | 109 | 109 |
| C2_ai | overall | | | | −2.0 | −2.0 | −2.8! | −3.6! | −2.5! | 0.5 | 95 | 101 | 96 | 89 |
| CW_ai | cat1-A | 100.1 | 100.1 | | | | | | | | 100 | 102 | 119 | 99 |
| CW_ai | cat1-B | 100.0 | | | | | | | | | 105 | 96 | 100 | 101 |
| CW_ai | cat3-fused | 100.1 | 100.0 | 99.9 | | | | | | | 101 | 101 | 105 | 104 |
| CW_ai | cat3-frame | 82.4 | | 99.9 | | | | | | | 97 | 99 | 114 | 117 |
| CW_ai | overall | 97.0 | 100.0! | 99.9 | | | | | | | 102 | 99 | 109 | 102 |
| CY_ai | cat1-A | | | | | | −7.7 | −7.7 | −7.7 | | 100 | 103 | 122 | 101 |
| CY_ai | cat3-fused | | | | | | −2.7 | −2.7 | −2.7 | −0.9 | 101 | 102 | 96 | 101 |
| CY_ai | cat3-frame | | | | | | | | | −0.4 | 97 | 99 | 136 | 136 |
| CY_ai | overall | | | | | | −7.1 | −7.1 | −7.1 | −0.6 | 100 | 102 | 122 | 107 |

NOTE — Condition CY metrics reported using Hausdorff PSNR.

Table 2 – Summary performance of octree geometry and RAHT attribute coding using release v9.0 relative to v8.0 results

| | | BPP Ratio [%] | | | BD-Rate [Δ%] | | | | | | Avg. of ratio maxrssk [%] | | Ratio of avg. runtime [%] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Condition | Class | Geometry | Colour | Refl | D1 | D2 | Y | Cb | Cr | R | Encoder | Decoder | Encoder | Decoder |
| C1_ai | cat1-A | | | | | | 0.5 | 0.2 | 0.7 | | 101 | 112 | 100 | 95 |
| C1_ai | cat1-B | | | | | | 0.3 | 0.1 | −0.2 | | 102 | 103 | 89 | 83 |
| C1_ai | cat3-fused | | | | | | −0.2 | −0.3 | −0.3 | 0.2 | 107 | 116 | 77 | 75 |
| C1_ai | cat3-frame | | | | | | | | | −1.2 | 97 | 99 | 94 | 89 |
| C1_ai | overall | | | | | | 0.4 | 0.1 | 0.2 | −0.8 | 101 | 107 | 93 | 88 |
| C2_ai | cat1-A | | | | −1.0 | −0.9 | −0.7 | −1.0 | −0.8 | | 92 | 107 | 93 | 105 |
| C2_ai | cat1-B | | | | −2.4 | −2.4 | −3.4 | −5.3 | −4.0 | | 103 | 110 | 94 | 94 |
| C2_ai | cat3-fused | | | | 0.1 | 0.1 | 0.1 | −0.2 | −0.1 | −0.1 | 106 | 124 | 93 | 90 |
| C2_ai | cat3-frame | | | | −4.5 | −4.4 | | | | −0.3 | 97 | 101 | 91 | 94 |
| C2_ai | overall | | | | −2.0 | −2.0 | −2.0 | −3.0 | −2.3 | −0.3 | 98 | 108 | 93 | 98 |

Table 3 – Summary performance of trisoup geometry and lifting based attribute coding using release v9.0 relative to v8.0 results

| | | BPP Ratio [%] | | | BD-Rate [Δ%] | | | | | | Avg. of ratio maxrssk [%] | | Ratio of avg. runtime [%] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Condition | Class | Geometry | Colour | Refl | D1 | D2 | Y | Cb | Cr | R | Encoder | Decoder | Encoder | Decoder |
| C2_ai | cat1-A | | | | −2.4 | −3.7 | −5.5 | −1.8 | −1.2 | | 96 | 91 | 95 | 86 |

[3] pcc-tmc13-tmc13v9.0_octree_predlift__vs__tmc13v8.0_octree_predlift.xlsm
[4] pcc-tmc13-tmc13v9.0_octree_raht__vs__tmc13v8.0_octree_raht.xlsm
[5] pcc-tmc13-tmc13v9.0_trisoup_lift__vs__tmc13v8.0_trisoup_lift.xlsm
[6] pcc-tmc13-tmc13v9.0_trisoup_raht__vs__tmc13v8.0_trisoup_raht.xlsm

Table 4 – Summary performance of trisoup geometry and RAHT attribute coding using release v9.0 relative to v8.0 results

| | | BPP Ratio [%] | | | BD-Rate [Δ%] | | | | | | Avg. of ratio maxrssk [%] | | Ratio of avg. runtime [%] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Condition | Class | Geometry | Colour | Refl | D1 | D2 | Y | Cb | Cr | R | Encoder | Decoder | Encoder | Decoder |
| C2_ai | cat1-A | | | | −2.4 | −3.7 | −6.1 | −4.5 | −3.6 | | 97 | 96 | 92 | 89 |
| C2_ai | cat1-B | | | | −7.7 | −5.8 | −7.8 | −6.1 | −5.4 | | 97 | 95 | 94 | 86 |
| C2_ai | overall | | | | −5.1 | −4.8 | −7.0 | −5.3 | −4.5 | | 97 | 95 | 93 | 87 |

## Cross checking

A cross-check of releasea v9.0 and v9.0-rc1 were kindly performed by BlackBerry, Panasonic and Sony over all CTC configurations (octree, trisoup, RAHT, predlift) and conditions (C1, C2, CW, CX). All cross-checks[7][8][9][10]completed successfully and any deviation in exact reported results due to average calculation methods is negligible.

## Tool verification

Following the integration of each tool, tests are made to verify the integration with differential results provided with the report.

Caution is required when interpreting performance figures since integration 9 includes an update to the common test conditions that enables LoD attribute coding for cat1-B sequences. Prior to this, for LoD configurations, attribute coding for cat1-B sequences is excluded from conditions C2 and CW, while cat1-B sequences are not used in conditions C1 and CY. This results in reporting of runtime increases (due to the increase in test set size) and increases in the colour bpp ratio (due to how the CTC computes this measure).

The general progression of coding performance with successive integrations is shown in tables 5 to 10.

Table 5 – Octree & lifting transform progression – C1_ai,overall

| | | BPP Ratio [%] | | | BD-Rate [Δ%] | | | | | | Avg. of ratio maxrssk [%] | | Ratio of avg. runtime [%] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Condition | Class | Geometry | Colour | Refl | D1 | D2 | Y | Cb | Cr | R | Encoder | Decoder | Encoder | Decoder |
| C1_ai | 00=neighb | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 100 | 100 | 101 | 98 |
| C1_ai | 01=geomquant | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 100 | 100 | 100 | 99 |
| C1_ai | 02=bypass | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 100 | 100 | 101 | 100 |
| C1_ai | 04=parallel | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 119 | 120 | 104 | 104 |
| C1_ai | 05=angular | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 100 | 100 | 108 | 106 |
| C1_ai | 07=lod | | | | | | −0.0 | 0.0 | 0.0 | 0.0 | 100 | 99 | 107 | 104 |
| C1_ai | 09=dist2 | | | | | | 0.9! | 0.4! | 0.8! | 0.0 | 100 | 100 | 225 | 182 |
| C1_ai | 10=qp51 | | | | | | 1.1! | 2.4! | 3.1! | 0.1 | 100 | 100 | 225 | 180 |
| C1_ai | 11=cat3frame | | | | | | 1.1! | 2.4! | 3.1! | 0.1 | 100 | 100 | 224 | 179 |
| C1_ai | 12a=slices | | | | | | 1.1! | 2.4! | 3.1! | 0.1 | 98 | 100 | 225 | 183 |
| C1_ai | 12b=slices | | | | | | 1.2! | 2.6! | 3.3! | 0.1 | 99 | 99 | 226 | 181 |
| C1_ai | 13=scalable | | | | | | 1.2! | 2.6! | 3.3! | 0.1 | 99 | 99 | 224 | 178 |
| C1_ai | 14=rc1fixes | | | | | | 1.1! | 2.5! | 3.2! | 0.1 | 100 | 102 | 227 | 184 |

Table 6 – Octree & lifting transform progression – C2_ai,overall

| | | BPP Ratio [%] | | | BD-Rate [Δ%] | | | | | | Avg. of ratio maxrssk [%] | | Ratio of avg. runtime [%] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Condition | Class | Geometry | Colour | Refl | D1 | D2 | Y | Cb | Cr | R | Encoder | Decoder | Encoder | Decoder |
| C2_ai | 00=neighb | | | | 0.1 | 0.1 | 0.0! | 0.0! | 0.0! | 0.0 | 100 | 100 | 100 | |
| C2_ai | 01=geomquant | | | | 0.1 | 0.1 | 0.0! | 0.0! | 0.0! | 0.0 | 100 | 101 | 102 | |
| C2_ai | 02=bypass | | | | 0.1 | 0.1 | 0.0! | 0.0! | 0.0! | 0.0 | 100 | 101 | 102 | 97 |
| C2_ai | 04=parallel | | | | 0.1 | 0.1 | 0.0! | 0.0! | 0.0! | 0.0 | 101 | 102 | 102 | 98 |
| C2_ai | 05=angular | | | | −0.3 | −0.3 | 0.0! | 0.0! | 0.0! | 0.0 | 100 | 101 | 99 | 100 |
| C2_ai | 07=lod | | | | −0.3 | −0.3 | 0.1! | 0.2! | −0.1! | 0.0 | 100 | 101 | 102 | |
| C2_ai | 09=dist2 | | | | −0.3 | −0.3 | −2.3! | −4.5! | −3.9! | 0.0 | 104 | 120 | 154 | 129 |
| C2_ai | 10=qp51 | | | | −0.3 | −0.3 | −2.2! | −2.7! | −1.6! | 0.1 | 104 | 120 | 154 | 127 |
| C2_ai | 11=cat3frame | | | | −0.5 | −0.5 | −2.2! | −2.7! | −1.6! | 0.5 | 104 | 120 | 154 | 125 |
| C2_ai | 12a=slices | | | | −2.0 | −2.0 | −2.8! | −3.6! | −2.5! | 0.5 | 98 | 120 | 147 | |
| C2_ai | 12b=slices | | | | −1.9 | −1.9 | −2.8! | −3.5! | −2.5! | 0.5 | 98 | 120 | 147 | 125 |
| C2_ai | 13=scalable | | | | −1.9 | −1.9 | −2.8! | −3.5! | −2.5! | 0.5 | 98 | 120 | 150 | 125 |
| C2_ai | 14=rc1fixes | | | | −2.0 | −2.0 | −2.8! | −3.6! | −2.5! | 0.5 | 99 | 122 | 146 | 130 |

[7] report_tmc13v9.0_octree_predlift_apple__vs__bb.txt
[8] report_tmc13v9.0_trisoup_predlift_apple__vs__bb.txt
[9] report_tmc13v9.0_octree_raht_apple__vs__bb.txt
[10] report_tmc13v9.0_trisoup_raht_apple__vs__bb.txt

Table 7 – Octree & predicting transform progression – CW_ai,overall

| | | BPP Ratio [%] | | | BD-Rate [Δ%] | | | | | | Avg. of ratio maxrssk [%] | | Ratio of avg. runtime [%] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Condition | Class | Geometry | Colour | Refl | D1 | D2 | Y | Cb | Cr | R | Encoder | Decoder | Encoder | Decoder |
| CW_ai | 00=neighb | 100.0 | 100.0! | 100.0 | | | | | | | 100 | 100 | 98 | 102 |
| CW_ai | 01=geomquant | 100.0 | 100.0! | 100.0 | | | | | | | 101 | 100 | 97 | 99 |
| CW_ai | 02=bypass | 100.0 | 100.0! | 100.0 | | | | | | | 101 | 100 | 99 | 103 |
| CW_ai | 04=parallel | 100.0 | 100.0! | 100.0 | | | | | | | 111 | 112 | 103 | 102 |
| CW_ai | 05=angular | 97.0 | 100.0! | 100.0 | | | | | | | 100 | 100 | 104 | 103 |
| CW_ai | 07=lod | 97.0 | 100.0! | 99.9 | | | | | | | 100 | 100 | 101 | 105 |
| CW_ai | 09=dist2 | 97.0 | 108.9! | 99.9 | | | | | | | 109 | 113 | 142 | 124 |
| CW_ai | 10=qp51 | 97.0 | 108.9! | 99.9 | | | | | | | 109 | 113 | 144 | 126 |
| CW_ai | 11=cat3frame | 97.0 | 108.9! | 99.9 | | | | | | | 109 | 113 | 139 | 126 |
| CW_ai | 12a=slices | 97.0 | 108.9! | 99.9 | | | | | | | 107 | 113 | 141 | 123 |
| CW_ai | 12b=slices | 97.0 | 108.9! | 99.9 | | | | | | | 107 | 111 | 141 | 125 |
| CW_ai | 13=scalable | 97.0 | 108.9! | 99.9 | | | | | | | 107 | 111 | 137 | 123 |
| CW_ai | 14=rc1fixes | 97.0 | 108.9! | 99.9 | | | | | | | 108 | 112 | 142 | 127 |

Table 8 – Octree & RAHT progression – C1_ai,cat1-A

| | | BPP Ratio [%] | | | BD-Rate [Δ%] | | | | | | Avg. of ratio maxrssk [%] | | Ratio of avg. runtime [%] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Condition | Class | Geometry | Colour | Refl | D1 | D2 | Y | Cb | Cr | R | Encoder | Decoder | Encoder | Decoder |
| C2_ai | 05=angular | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 100 | 100 | 102 | 103 |
| C2_ai | 08=raht | | | | 0.0 | 0.0 | 0.2 | 0.1 | 0.0 | | 101 | 104 | 105 | 101 |
| C2_ai | 12a=slices | | | | −1.0 | −0.9 | −0.7 | −1.0 | −0.8 | | 91 | 105 | 94 | 102 |
| C2_ai | 12b=slices | | | | −0.9 | −0.9 | −0.7 | −1.0 | −0.8 | | 91 | 105 | 96 | 103 |
| C2_ai | 14=rc1fixes | | | | −1.0 | −0.9 | −0.7 | −1.0 | −0.8 | | 92 | 107 | 93 | 103 |

Table 9 – Octree & RAHT progression – C1_ai,cat1-B

| | | BPP Ratio [%] | | | BD-Rate [Δ%] | | | | | | Avg. of ratio maxrssk [%] | | Ratio of avg. runtime [%] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Condition | Class | Geometry | Colour | Refl | D1 | D2 | Y | Cb | Cr | R | Encoder | Decoder | Encoder | Decoder |
| C2_ai | 05=angular | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 100 | 100 | 98 | 98 |
| C2_ai | 08=raht | | | | 0.0 | 0.0 | 0.2 | 0.4 | 0.4 | | 104 | 108 | 98 | 93 |
| C2_ai | 12a=slices | | | | −2.4 | −2.4 | −3.4 | −5.4 | −4.1 | | 100 | 108 | 91 | 91 |
| C2_ai | 12b=slices | | | | −2.3 | −2.3 | −3.3 | −5.1 | −3.9 | | 102 | 107 | 92 | 92 |
| C2_ai | 14=rc1fixes | | | | −2.4 | −2.4 | −3.4 | −5.3 | −4.0 | | 103 | 110 | 94 | 93 |

Table 10 – Trisoup & lifting transform progression – C2_ai,cat1-A

| | | BPP Ratio [%] | | | BD-Rate [Δ%] | | | | | | Avg. of ratio maxrssk [%] | | Ratio of avg. runtime [%] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Condition | Class | Geometry | Colour | Refl | D1 | D2 | Y | Cb | Cr | R | Encoder | Decoder | Encoder | Decoder |
| C2_ai | 05=angular | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 100 | 100 | 102 | 101 |
| C2_ai | 06=trisoup | | | | 5.8 | 0.4 | −1.8 | −1.3 | −1.3 | | 99 | 91 | 98 | 87 |
| C2_ai | 12a=slices | | | | −2.8 | −4.0 | −5.6 | −2.3 | −1.4 | | 94 | 90 | 95 | 86 |
| C2_ai | 12b=slices | | | | −5.1 | −3.7 | −5.8 | −1.9 | −1.3 | | 94 | 91 | 95 | 86 |
| C2_ai | 14=rc1fixes | | | | −2.4 | −3.7 | −5.5 | −1.8 | −1.2 | | 96 | 91 | 95 | 87 |

Table 11 – List of integration reports

| Integration | Config | Reference | Reporting workbook |
|---|---|---|---|
| 00=neighb | Octree-LoD | v8.0 | pcc-tmc13-tmc13v8.1+integration00=neighb_octree_predlift.xlsm |
| 01=geomquant | Octree-LoD | 00=neighb | pcc-tmc13-tmc13v8.1+integration01=geomquant_octree_predlift.xlsm |
| 02=bypass | Octree-LoD | 01=geomquant | pcc-tmc13-tmc13v8.1+integration02=bypass_octree_predlift.xlsm |
| 04=parallel | Octree-LoD | 02=bypass | pcc-tmc13-tmc13v8.1+integration04=parallel_octree_predlift.xlsm |
| 05=angular | Octree-LoD | 04=parallel | pcc-tmc13-tmc13v8.1+integration05=angular_octree_predlift.xlsm |
| 07=lod | Octree-LoD | 05=angular | pcc-tmc13-tmc13v8.1+integration07=lod_octree_predlift.xlsm |
| 09=dist2 | Octree-LoD | 07=lod | pcc-tmc13-tmc13v8.1+integration09=dist2_octree_predlift.xlsm |
| 10=qp51 | Octree-LoD | 09=dist2 | pcc-tmc13-tmc13v8.1+integration10=qp51_octree_predlift.xlsm |
| 11=cat3frame | Octree-LoD | 10=qp51 | pcc-tmc13-tmc13v8.1+integration11=cat3frame_octree_predlift.xlsm |
| 12a=slices | Octree-LoD | 11=cat3frame | pcc-tmc13-tmc13v8.1+integration12a=slices_octree_predlift.xlsm |
| 12b=slices | Octree-LoD | 12a=slices | pcc-tmc13-tmc13v8.1+integration12b=slices_octree_predlift.xlsm |
| 13=scalable | Octree-LoD | 12b=slices | pcc-tmc13-tmc13v8.1+integration13=scalable_octree_predlift.xlsm |
| 14=rc1fixes | Octree-LoD | 13=scalable | pcc-tmc13-tmc13v8.1+integration14=rc1fixes_octree_predlift.xlsm |
| 05=angular | Octree-RAHT | v8.0 | pcc-tmc13-tmc13v8.1+integration05=angular_octree_raht.xlsm |
| 08=raht | Octree-RAHT | 05=angular | pcc-tmc13-tmc13v8.1+integration08=raht_octree_raht.xlsm |
| 12a=slices | Octree-RAHT | 08=raht | pcc-tmc13-tmc13v8.1+integration12a=slices_octree_raht.xlsm |
| 12b=slices | Octree-RAHT | 12a=slices | pcc-tmc13-tmc13v8.1+integration12b=slices_octree_raht.xlsm |
| 14=rc1fixes | Octree-RAHT | 12b=slices | pcc-tmc13-tmc13v8.1+integration14=rc1fixes_octree_raht.xlsm |
| 05=angular | Trisoup-LoD | v8.0 | pcc-tmc13-tmc13v8.1+integration05=angular_trisoup_predlift.xlsm |
| 06=trisoup | Trisoup-LoD | 05=angular | pcc-tmc13-tmc13v8.1+integration06=trisoup_trisoup_predlift.xlsm |
| 12a=slices | Trisoup-LoD | 06=trisoup | pcc-tmc13-tmc13v8.1+integration12a=slices_trisoup_predlift.xlsm |
| 12b=slices | Trisoup-LoD | 12a=slices | pcc-tmc13-tmc13v8.1+integration12b=slices_trisoup_predlift.xlsm |
| 14=rc1fixes | Trisoup-LoD | 12b=slices | pcc-tmc13-tmc13v8.1+integration14=rc1fixes_trisoup_predlift.xlsm |

**Integration 0 — Geometry occupancy permutation simplification**

m51595: simplification of neighbourhood mapping

**Integration 1 — Geometry quantisation fixes**

m52400: disable planar mode when quantisation can interfere
m52521: add clipping to scaling process
m52521: don't use effective node size to enable features
m52521: unify per-slice and in-tree quantisation signalling
m52400: fix quantisation interaction with qtbt

**Integration 2 — Chunked bypass sub-stream**

m51024: refactor schrodinger to use read/write byte interface
m51024: add chunk interleaved aec/bypass stream

**Integration 4 — Parallel octree layers**

m50930: add parallel octree coding

**Integration 5 — Angular geometry occupancy contextualisation**

m50642: angular coding mode
m52343: update implicit qtbt rules for angular mode

The high-level syntax of the angular coding mode has been updated to correctly take account of the position of the slice when calculating the scanner origin. To align with other adoptions, the signalled scanner origin is now signalled relative to the sequence bounding box.

A potential issue has been addressed when a node has a laser index of 255 and is unable to find a 'best' laser index.

**Integration 6 — Trisoup**

m50757: control trisoup voxelisation resolution
m52280: use single context to signal segment_indicator

**Integration 7 — LoD attribute coding**

m52719: avoid double quantisation in forward inter-component prediction
m51010: change nearest neighbour search order
m50765: ignore rate in reflectance predictor selection
m50765: skip n-neighbour average reflectance predictor

**Integration 8 — RAHT attribute coding**

m51374: add early termination of raht prediction
m52341: add region-wise quantization support for raht coding
m52391: fix raht coding of a single point

**Integration 9 — CTC: Automatic lod dist$^2$ calculation**

m52524: automatic calculation of LoD squared distance parameter

**Integration 10 — CTC: QP51 limit**

m52501: limit qp to 51 for 8bit attributes

**Integration 11 — CTC: cat3-frame sequence bounding box**

m52525: set sequence bounding box for cat3 multi-frames sequences

**Integration 12a — CTC: slice partitioning fixes**

m52732: add encoder option to enforce level limits
m52569: don't partition small point clouds
m52336: fix use of wrong cloud in slice merge/split process
m52319: constrain slice partitions to trisoup node size

**Integration 12b — CTC: slice partitioning scheme**

m52337: add uniform square partitioning method

The integration of m52337 revealed that the method presented and adopted at the 129th meeting does not obey the constraint on the maximum number of points per slice. A modified version has been integrated that resolves this issue. However, compression performance is decreased.

After further investigation, fixes have been applied in integration 14.

**Integration 13 — CTC: slice partitioning**

m50743: generalise merging of scalable LoDs
m51408: retained node selection

**Integration 14 — Post rc1 fixes**

slice/m52337: fix incorrect minimum in adjacent slice search
slice: restore specialised octree partition refinement methods
entropy: fix incorrect flushing behaviour with no pending output byte
geom: fix minimum maxNodeSizeLog2 when coding a single point
attr: fix invalid array access in dist2 estimation with too few points
raht: fix access to reserved portion of parent neighbour arrays

## Release v9.0

This release contains the integration of, or aspects relating to: m50642, m50743, m50757, m50765, m50930, m51010, m51024, m51374, m51408, m51595, m52280, m52319, m52336, m52337, m52341, m52343, m52391, m52400, m52501, m52521, m52524, m52525, m52569, m52719, and m52732 [4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28].

It has not been possible to integrate the following adoptions:

- m52521: signalling quantisation depth on a per-level basis. This adoption fundamentally conflicts with another higher-priority adoption (m52400 planar mode interaction fix) made at the same time. This topic should be re-reviewed at the next meeting.
- m52517: ctc change to use geometry quantisation where possible. It is not yet clear how to make the desired CTC change. To reduce associated risks of undesired interactions, no change has been made to the CTC at this point. Further study should be made in the context of the ad hoc group and CE 13.29.

### General comments

- A new encoder option has been added to enforce level constraints. At present, this checks that slices have 1,100,000 points or fewer. It is enabled by default. If the geometry coding produces more points than the limit, the encoder will abort.
- The software now supports writing multi-frame sequences using a printf-like `%d` directive to act as a placeholder for the current frame number. When encoding, parameter sets are repeated for each frame, with the usual caveat that they must not change.
- CTC configurations are provided for the following test conditions:

octree + pred/lift transforms [C1, C2, CW, CY]
octree + RAHT [C1, C2]
trisoup + pred/lift transforms [C2]
trisoup + RAHT [C2]

- A review of the CTC conditions is still required for the next meeting, since several test points cause issues in calculating reportable results. In particular:
  - some sequences have so few points that decoding is instantaneous (causes issues for geometric mean).
  - some trisoup test points are lossless.
  - some trisoup geometry configuration results are identical over multiple test points causing the failure of BD-rate calculations.
  - the current sequence categorisation does not facilitate identifying the type of content providing compression gains or losses.
- The software may be configured to output either ASCII or binary ply files using the `outputBinaryPly` option. Be aware that under certain test conditions this will affect the re-scaled geometry values due to the difference in precision of the two representations. Anchor results have been generated using the ASCII option.

## Changes between v8.1 and v9.0

geom: remove unused processedPointCount
geom/m51595: simplification of neighbourhood mapping
geom/m52400: disable planar mode when quantisation can interfere
geom/m52521: add clipping to scaling process
geom/m52521: don't use effective node size to enable features
geom/m52521: unify per-slice and in-tree quantisation signalling
geom/m52400: fix quantisation interaction with qtbt
entropy/m51024: refactor schrodinger to use read/write byte interface
entropy/m51024: add chunk interleaved aec/bypass stream
geom: tidy per-level octree setup
geom: encapsulate planar state in OctreePlanarState
entropy: enable copying of DualLutCoder
geom: enable copying of CtxMapOctreeOccupancy
geom: enable copying of OctreePlanarState
geom: enable copying of GeometryOctreeEncoder/Decoder
geom/m50930: add parallel octree coding
geom/m50642: angular coding mode
geom/m52343: update implicit qtbt rules for angular mode
trisoup/m50757: control trisoup voxelisation resolution
trisoup/m52280: use single context to signal segment_indicator
attr/m52719: avoid double quantisation in forward inter-component prediction
attr/m51010: refactor nearest neighbour update in search
attr/m51010: change nearest neighbour search order
attr/m50765: ignore rate in reflectance predictor selection
attr/m50765: skip n-neighbour average reflectance predictor
attr/m51374: add early termination of raht prediction
attr/m52341: add region-wise quantization support for raht coding

attr/m52391: fix raht coding of a single point
attr/m52524: automatic calculation of LoD squared distance parameter
cfg/m52524: enable LoD dist2 auto computation
cfg/m52501: limit qp to 51 for 8bit attributes
hls/m52525: only fix-up parameter sets once
cfg/m52525: disable partitioning for cat3-frame sequences
cfg/m52525: set sequence bounding box for cat3 multi-frames sequences
cli/m52732: add encoder option to enforce level limits
slice/m52569: don't partition small point clouds
slice/m52336: fix use of wrong cloud in slice merge/split process
slice/m52319: constrain slice partitions to trisoup node size
slice/m52337: add uniform square partitioning method
cli: report parameter parsing errors
attr/m50743: generalise merging of scalable LoDs
attr/m51408: retained node selection
release: update version to 9.0-rc1
tidy: fix indentation
slice/m52337: fix incorrect minimum in adjacent slice search
slice: restore specialised octree partition refinement methods
geom: refactor isPlanarNode
entropy: fix incorrect flushing behaviour with no pending output byte
geom: fix minimum maxNodeSizeLog2 when coding a single point
attr: fix invalid array access in dist2 estimation with too few points
raht: fix access to reserved portion of parent neighbour arrays
doc: document new/updated options in v9.0 release
release: update version to v9.0

**Location of changes**

```
cfg/octree-liftt-ctc-lossless-geom-lossy-attrs.yaml        |  69 +--
cfg/octree-liftt-ctc-lossy-geom-lossy-attrs.yaml           |  23 +-
cfg/octree-predt-ctc-lossless-geom-lossless-attrs.yaml     |  20 +-
cfg/octree-predt-ctc-lossless-geom-nearlossless-attrs.yaml |  65 +--
cfg/octree-raht-ctc-lossless-geom-lossy-attrs.yaml         |  13 +-
cfg/octree-raht-ctc-lossy-geom-lossy-attrs.yaml            |  13 +-
cfg/sequences-cat1.yaml                                    |  22 -
cfg/sequences-cat3.yaml                                    | 149 ++++-
cfg/trisoup-liftt-ctc-lossy-geom-lossy-attrs.yaml          |  58 +-
cfg/trisoup-raht-ctc-lossy-geom-lossy-attrs.yaml           |   2 +-
dependencies/schroedinger/schroarith.c                     |  51 +-
dependencies/schroedinger/schroarith.h                     |  68 +--
doc/README.options.md                                      |  99 +++-
doc/mpeg-pcc-tmc13-sw-manual.tex                           |   6 +-
tmc3/Attribute.h                                           |   4 +
tmc3/AttributeCommon.cpp                                   |   4 +-
tmc3/AttributeCommon.h                                     |   1 +
tmc3/AttributeDecoder.cpp                                  |  26 +-
tmc3/AttributeEncoder.cpp                                  | 141 ++++-
tmc3/CMakeLists.txt                                        |   3 +-
tmc3/DualLutCoder.h                                        |  18 +-
tmc3/PCCMisc.h                                             |  31 ++
tmc3/PCCTMC3Common.h                                       | 371 ++++++------
tmc3/PCCTMC3Encoder.h                                      |  16 +
```

```
tmc3/RAHT.cpp                                       | 128 ++++-
tmc3/RAHT.h                                         |  12 +-
tmc3/TMC3.cpp                                       | 131 ++++-
tmc3/decoder.cpp                                    |  33 +-
tmc3/encoder.cpp                                    | 185 +++++--
tmc3/entropychunk.h                                 | 370 +++++++++++++
tmc3/entropydirac.h                                 | 148 ++---
tmc3/geometry.h                                     |  14 +-
tmc3/geometry_octree.cpp                            | 386 ++++++++++----
tmc3/geometry_octree.h                              | 108 +++-
tmc3/geometry_octree_decoder.cpp                    | 893 ++++++++++++++++-------------
tmc3/geometry_octree_encoder.cpp                    | 976 ++++++++++++++++---------------
tmc3/geometry_trisoup.h                             |   3 +-
tmc3/geometry_trisoup_decoder.cpp                   |  31 +-
tmc3/geometry_trisoup_encoder.cpp                   |  49 +-
tmc3/hls.h                                          |  33 +-
tmc3/io_hls.cpp                                     |  92 +++-
tmc3/misc.cpp                                       |  79 +++
tmc3/partitioning.cpp                               | 412 +++++++++++++-
tmc3/partitioning.h                                 |  13 +
tmc3/quantization.cpp                               |  14 +-
tmc3/quantization.h                                 |   3 +-
46 files changed, 3773 insertions(+), 1613 deletions(-)
```

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