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Title: G-PCC TMC13v7 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 N18665 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-v7.0-rc1 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-v7.0” 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 N18665 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-tmc13v7.0-rc1_octree_raht_vs__tmc13v7.0-rc1_octree_predlift.xlsm](#)

²[pcc-tmc13-tmc13v7.0-rc1_trisoup_raht_vs__tmc13v7.0-rc1_trisoup_predlift.xlsm](#)

Summary analysis of v7.0-rc1 against v6.0 results

Compression results comparing v7.0-rc1 against v6.0 on test sequences from categories one and three using both the lod-based lifting/predicting transforms and RAHT are provided with this report³⁴⁵⁶ and summarised in tables 1 to 4.

Table 1 – Summary performance of octree geometry and predlift attribute coding using release v7.0-rc1 relative to v6.0 results

Condition	Class	BPP Ratio [%]			D1	D2	BD-Rate [Δ%]			R	Avg. of ratio maxrssk [%]		Ratio of avg. runtime [%]	
		Geometry	Colour	Refl			Y	Cb	Cr		Encoder	Decoder	Encoder	Decoder
C1_ai	cat1-A						0.5	0.5	0.7		99	66	108	100
C1_ai	cat3-fused						0.2	0.1	0.3	0.2	67	46	113	106
C1_ai	cat3-frame									0.0	112	100	109	107
C1_ai	overall						0.4	0.5	0.7	0.1	99	72	108	102
C2_ai	cat1-A				1.3	1.2	-1.4	-3.0	-3.5		258	89	1544	105
C2_ai	cat1-B				3.2!	3.3!					285	88	360	
C2_ai	cat3-fused				0.5	0.5	-2.1	-1.4	-0.8	-1.2	203	60	672	96
C2_ai	cat3-frame				0.0	0.0				-1.5	148	100	169	111
C2_ai	overall				1.9!	1.9!	-1.5!	-2.8!	-3.2!	-1.4	253	88	600	
CW_ai	cat1-A	100.4	100.3								105	69	117	109
CW_ai	cat1-B	100.1									97	81	121	103
CW_ai	cat3-fused	100.1	100.0	100.0							76	63	100	93
CW_ai	cat3-frame	100.0		100.0							112	100	98	96
CW_ai	overall	100.1	100.2!	100.0							101	78	115	104
CY_ai	cat1-A						1.1	1.1	1.1		106	69	113	107
CY_ai	cat3-fused						-0.2	-0.2	-0.2	0.0	79	63	98	93
CY_ai	cat3-frame									-0.3	112	100	108	105
CY_ai	overall						0.9	0.9	0.9	-0.2	105	75	110	105

NOTE — Condition CY metrics reported using Hausdorff PSNR.

Table 2 – Summary performance of octree geometry and RAHT attribute coding using release v7.0-rc1 relative to v6.0 results

Condition	Class	BPP Ratio [%]			D1	D2	BD-Rate [Δ%]			R	Avg. of ratio maxrssk [%]		Ratio of avg. runtime [%]	
		Geometry	Colour	Refl			Y	Cb	Cr		Encoder	Decoder	Encoder	Decoder
C1_ai	cat1-A						-38.9	-35.5	-35.5		81	58	192	229
C1_ai	cat1-B						-23.3!	-24.3!	-22.9!					
C1_ai	cat3-fused						-7.8	-8.3	-8.7	-15.4	25	15	354	483
C1_ai	cat3-frame									-9.1	97	84	247	293
C1_ai	overall						-29.8!	-28.6!	-28.0!	-11.0				
C2_ai	cat1-A				1.3!	1.2!	-37.7!	-36.3!	-36.6!		244	91	1780	
C2_ai	cat1-B				3.2!	3.2!	-21.3!	-20.3!	-18.1!					
C2_ai	cat3-fused				0.5	0.5	-20.5	-14.8	-14.4	-22.6	157	48	762	277
C2_ai	cat3-frame				0.0	0.0				-13.4	146	97	197	207
C2_ai	overall				1.8!	1.8!	-28.9!	-27.4!	-26.5!	-16.2				

Table 3 – Summary performance of trisoup geometry and lifting based attribute coding using release v7.0-rc1 relative to v6.0 results

Condition	Class	BPP Ratio [%]			D1	D2	BD-Rate [Δ%]			R	Avg. of ratio maxrssk [%]		Ratio of avg. runtime [%]	
		Geometry	Colour	Refl			Y	Cb	Cr		Encoder	Decoder	Encoder	Decoder
C2_ai	cat1-A				17.8	8.1	-0.5	-8.0	-7.8		143	72	743	103

Table 4 – Summary performance of trisoup geometry and RAHT attribute coding using release v7.0-rc1 relative to v6.0 results

Condition	Class	BPP Ratio [%]			D1	D2	BD-Rate [Δ%]			R	Avg. of ratio maxrssk [%]		Ratio of avg. runtime [%]	
		Geometry	Colour	Refl			Y	Cb	Cr		Encoder	Decoder	Encoder	Decoder
C2_ai	cat1-A				17.8	8.1	-41.2	-41.7	-42.7		137	70	911	169
C2_ai	cat1-B				36.5	11.9	-29.8	-35.0	-35.1		176	63	834	161
C2_ai	overall				27.6	10.1	-35.3	-38.2	-38.8		157	66	870	165

³[pcc-tmc13-tmc13v7.0-rc1_octree_predlift_vs__tmc13v6.0_octree_predlift.xlsm](#)

⁴[pcc-tmc13-tmc13v7.0-rc1_octree_raht_vs__tmc13v6.0_octree_raht.xlsm](#)

⁵[pcc-tmc13-tmc13v7.0-rc1_trisoup_lift_vs__tmc13v6.0_trisoup_lift.xlsm](#)

⁶[pcc-tmc13-tmc13v7.0-rc1_trisoup_raht_vs__tmc13v6.0_trisoup_raht.xlsm](#)

Cross checking

A cross-check of release-v7.0-rc1 was kindly performed by Panasonic, BlackBerry, and Sony over all CTC configurations (octree, trisoup, RAHT, predlift) and conditions (C1, C2, CW, CX). All cross-checks⁷⁸⁹¹⁰ 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. Only a single frame of the multi-frame sequences are used to reduce simulation time.

The general progression of coding performance with successive integrations is shown in tables 5 to 9.

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

Condition	Integration	BPP Ratio [%]			Refl	D1	D2	BD-Rate [Δ %]				R	Avg. of ratio maxrssk [%]		Ratio of avg. runtime [%]	
		Geometry	Colour					Y	Cb	Cr			Encoder	Decoder	Encoder	Decoder
C1_ai	01=intralodpred							0.0	0.0	0.0	0.0		100	100	98	97
C1_ai	02=unifylodneigh							-0.0	0.1	0.0	-0.0		100	100	103	103
C1_ai	02a=unifylodorder							0.0	0.0	0.0	-0.0		100	100	100	99
C1_ai	03=lodbacdep							-0.0	0.1	0.0	-0.0		100	100	101	101
C1_ai	04=isqrt							-0.0	0.0	0.0	-0.0		100	100	102	102
C1_ai	05=quant							-0.0	0.0	0.0	-0.0		100	100	100	100
C1_ai	06=recolour							-0.0	0.0	0.0	-0.0		100	100	100	102
C1_ai	08=slices							0.4	0.5	0.7	0.1		99	72	108	102

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

Condition	Integration	BPP Ratio [%]			Refl	D1	D2	BD-Rate [Δ %]				R	Avg. of ratio maxrssk [%]		Ratio of avg. runtime [%]	
		Geometry	Colour					Y	Cb	Cr			Encoder	Decoder	Encoder	Decoder
C2_ai	01=intralodpred					0.0!	0.0!	0.0!	0.0!	0.0!	0.0		100	100	101	
C2_ai	02=unifylodneigh					0.0!	0.0!	-0.0!	0.2!	-0.0!	-0.0		100	100	102	
C2_ai	02a=unifylodorder					0.0!	0.0!	0.0!	0.0!	0.0!	0.0		100	100	103	
C2_ai	03=lodbacdep					0.0!	0.0!	-0.0!	0.2!	-0.0!	-0.0		100	100	103	
C2_ai	04=isqrt					0.0!	0.0!	-0.0!	0.2!	-0.1!	-0.0		100	100	101	
C2_ai	05=quant					0.0!	0.0!	-0.0!	0.2!	-0.1!	-0.0		100	100	101	105
C2_ai	06=recolour					0.0!	0.0!	-2.1!	-3.7!	-4.1!	-1.6		107	100	329	104
C2_ai	08=slices					1.9!	1.9!	-1.5!	-2.8!	-3.2!	-1.4		253	88	600	

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

Condition	Integration	BPP Ratio [%]			Refl	D1	D2	BD-Rate [Δ %]				R	Avg. of ratio maxrssk [%]		Ratio of avg. runtime [%]	
		Geometry	Colour					Y	Cb	Cr			Encoder	Decoder	Encoder	Decoder
CW_ai	01=intralodpred	100.0	100.0!	100.0									100	100	101	101
CW_ai	02=unifylodneigh	100.0	100.3!	100.0									100	101	103	104
CW_ai	02a=unifylodorder	100.0	100.0!	100.0									100	100	102	102
CW_ai	03=lodbacdep	100.0	100.2!	100.0									100	101	104	102
CW_ai	04=isqrt	100.0	100.2!	100.0									100	102	101	103
CW_ai	05=quant	100.0	100.2!	100.0									100	102	100	102
CW_ai	06=recolour	100.0	100.2!	100.0									100	102	109	108
CW_ai	08=slices	100.1	100.2!	100.0									101	78	115	104

Table 8 – Octree & RAHT progression – C2_ai,cat1-A

Condition	Integration	BPP Ratio [%]			Refl	D1	D2	BD-Rate [Δ %]				R	Avg. of ratio maxrssk [%]		Ratio of avg. runtime [%]	
		Geometry	Colour					Y	Cb	Cr			Encoder	Decoder	Encoder	Decoder
C2_ai	04=tdpred					0.0!	0.0!	-36.9!	-34.0!	-34.1!			99	107	116	
C2_ai	05=quant					0.0!	0.0!	-36.9!	-34.0!	-34.1!			99	107	112	
C2_ai	06=recolour					0.0!	0.0!	-38.2!	-37.3!	-37.6!			115	107	1685	
C2_ai	08=slices					1.3!	1.2!	-37.7!	-36.3!	-36.6!			244	91	1780	

Integration 1 — intra-LoD prediction

Fixes an issue where intra-LoD prediction is not applied to the top layer.

Octree-LoD: [pcc-tmc13-tmc13v6.0+integration01_octree_predlift.xlsm](#)

⁷[report_tmc13v7.0-rc1_octree_predlift_apple_vs__panasonic.txt](#)

⁸[report_tmc13v7.0-rc1_trisoup_predlift_apple_vs__panasonic.txt](#)

⁹[report_tmc13v7.0-rc1_octree_raht_apple_vs__panasonic.txt](#)

¹⁰[report_tmc13v7.0-rc1_trisoup_raht_apple_vs__panasonic.txt](#)

Table 9 – Octree & RAHT progression – C2_ai,cat1-B

Condition	Integration	BPP Ratio [%]				BD-Rate [$\Delta\%$]						Avg. of ratio maxrssk [%]			Ratio of avg. runtime [%]	
		Geometry	Colour	Refl		D1	D2	Y	Cb	Cr		Encoder	Decoder		Encoder	Decoder
C2_ai	04=tdpred					-0.0!	-0.0!	-23.5!	-23.8!	-21.7!						
C2_ai	05=quant					-0.0!	-0.0!	-23.5!	-23.8!	-21.7!						
C2_ai	06=recolour					-0.0!	-0.0!	-24.4!	-25.0!	-23.2!						
C2_ai	08=slices					3.2!	3.2!	-21.3!	-20.3!	-18.1!						

Integration 2 — unification / consistency of LoD generation

Removes the following inconsistencies in LoD generation:

- LoD point order

Octree-LoD: [pcc-tmc13-tmc13v6.0+integration02a_octree_predlift.xlsm](#)

- Neighbour insertion behaviour

Octree-LoD: [pcc-tmc13-tmc13v6.0+integration02_octree_predlift.xlsm](#)

Integration 3 — geometry, contextualisation by unoccupied child neighbours

Additional contextualisation of occupancy bits based on the presence of unoccupied adjacent child neighbours.

Results compared to integration 1:

Octree-LoD: [pcc-tmc13-tmc13v6.0+integration03_octree_predlift.xlsm](#)

Integration 4 — transform domain predicted raht

Changing the order of forward RAHT operations and the addition of transform domain prediction. NB, since a change is made to the definition of iSqrt, results are shown for the LoD attribute coding methods.

Octree-RAHT: [pcc-tmc13-tmc13v6.0+integration04_octree_raht.xlsm](#)

Octree-LoD: [pcc-tmc13-tmc13v6.0+integration04_octree_predlift.xlsm](#)

Integration 5 — quantization optimisation

Optimises encoder coefficient quantization through use of multiplicative reciprocals in order to avoid division.

Octree-RAHT: [pcc-tmc13-tmc13v6.0+integration05_octree_raht.xlsm](#)

Octree-LoD: [pcc-tmc13-tmc13v6.0+integration05_octree_predlift.xlsm](#)

Integration 6 — recolouring

Refinement to recolouring.

Octree-RAHT: [pcc-tmc13-tmc13v6.0+integration06_octree_raht.xlsm](#)

Octree-LoD: [pcc-tmc13-tmc13v6.0+integration06_octree_predlift.xlsm](#)

Integration 7 — non-CTC adoptions

Integrations that do not affect the common test conditions:

- Per-layer luma/chroma qp offsets
- AEC bypass-bin sub-stream

Integration 8 — slices

Changes the order of geometry quantisation and recolouring, and limits each slice to 1.1 million points.

Octree-RAHT: [pcc-tmc13-tmc13v6.0+integration08_octree_raht.xlsm](#)

Octree-LoD: [pcc-tmc13-tmc13v6.0+integration08_octree_predlift.xlsm](#)

Release v7.0-rc1

This release contains the integration of, or aspects relating to: m47378, m47834, m47927, m48892, m48918, m49121, m49407, m49628, m49629, m49630, and N18665 [4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 1]

General comments

- Remaining non-normative, non-CTC adoptions will be integrated in release v7.1.
- Morton codes are now represented as signed values. This avoids errors based upon the belief that type of an expression involving the subtraction of unsigned values is always signed.
- Please avoid the use of global variables: they make tracking state more difficult and accidental resource leaks more likely.
- 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 v6.0 and v7.0-rc1

2019-08-05 scripts: update sample makefile with current `pc_error` parameters

2019-08-05 tools: find perl using `/usr/bin/env`

2019-08-05 tools/cfg-gen: make prefix option apply to template output

2019-08-05 tools/cfg-gen: fix ability to pass options to inner script after `'–'` escape

2019-08-05 attr/m49628: use intra lod prediction in top layer

2019-08-12 attr/m49629: order lod points in ascending morton order

2019-08-12 general: always use `int64_t` to represent morton codes

2019-08-12 attr/m49628: unify neighbour insertion behaviour for single/multi lod

2019-08-12 attr/m49628: remove specialised single layer lod generator
 2019-08-12 attr/m49630: permit unconditional signalling of prediction index
 2019-08-12 attr: remove unused raht_binary_level_threshold
 2019-08-12 maths: adjust integer square root initial approximation
 2019-08-12 attr/m47378: top-down raht
 2019-08-12 attr/m47378: raht domain prediction from upsampled ancestors
 2019-08-12 attr/m47378: increase fixed point precision to 15bit
 2019-08-12 attr: move fixed point adjustment out of quantization functions
 2019-08-12 attr: refactor quantisation state and detail into Quantizer class
 2019-08-12 attr/m48918: use multiplicative inverse for quantisation
 2019-08-12 recolour/m49407: improve point cloud recolouring
 2019-08-12 enc: add placeholder EncoderAttributeParams
 2019-08-12 attr/m47834: add support for per-layer luma/chroma qp offsets
 2019-08-12 entropy: disable aec trailing 0xff-byte pruning
 2019-08-12 entropy/m47927: add ability to put bypass bins in separate reverse stream
 2019-08-12 slices/m48892: perform geometry quantisation prior to slice partitioning
 2019-08-12 slices/m48892: limit the number of points per slice
 2019-08-12 slices/m49121: constrain slice partitions to trisoup node size
 2019-08-12 cfg/N18665: update cat2 sequence lengths

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