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CODING OF MOVING PICTURES AND AUDIO

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Source: 3DG

Title: G-PCC TMC13v11 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 N19584 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-v11.0 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
```

Anchor results are produced using pc_error version release-0.13.5. Due to the nature of the cluster environment, reported run time changes are approximate only.

Subsequent to verification, the tag “release-v11.0” 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 N19584 are reported in the enclosed reporting sheets¹²³:

- 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-tmc13v11.0_octree_raht_vs__tmc13v11.0_octree_predlift.xlsm](#)

²[pcc-tmc13-tmc13v11.0_trisoup_raht_vs__tmc13v11.0_trisoup_predlift.xlsm](#)

³[pcc-tmc13-tmc13v11.0_predgeom_predlift_vs__tmc13v11.0_octree_predlift.xlsm](#)

Summary analysis of v11.0 against v11.0 results

Compression results comparing v11.0 against v11.0 on test sequences from categories one and three using both the lod-based lifting/predicting transforms and RAHT are provided with this report⁴⁵⁶⁷ and summarised in tables 1 to 4.

Table 1 – Summary performance of octree geometry and prelift attribute coding using release v11.0 relative to v11.0 results

Condition	Class	BPP Ratio [%]			BD-Rate [$\Delta\%$]						Avg. of ratio maxrssk [%]		Ratio of avg. runtime [%]		
		Geometry	Colour	Refl	D1	D2	Y	Cb	Cr	R	Encoder	Decoder	Encoder	Decoder	
C1_ai	cat1-A				-0.4	-0.4	-7.9	-10.9	-12.7			108	106	63	74
C1_ai	cat1-B				0.0	0.0	-3.5	-4.8	-6.0			102	103	64	92
C1_ai	cat3-fused				-0.2	-0.2	-1.4	-1.5	-1.9	-1.4		106	100	47	60
C1_ai	cat3-frame				-0.0	-0.0				-8.4		365	384	64	85
C1_ai	overall				-0.2	-0.2	-5.4	-7.3	-8.8	-6.3		137	139	63	82
C2_ai	cat1-A				-0.1	-0.1	-5.1	-8.5	-12.5			115	118	96	63
C2_ai	cat1-B				-0.1	-0.1	-3.0	-4.6	-7.2			106	107	87	77
C2_ai	cat3-fused				0.1	0.1	-1.9	-1.1	-2.4	-1.1		104	105	90	85
C2_ai	cat3-frame				0.2	0.2				-2.5		104	100	92	101
C2_ai	overall				-0.1	-0.1	-3.9	-6.1	-9.3	-2.0		109	110	91	74
CW_ai	cat1-A	99.8	99.4									112	109	78	97
CW_ai	cat1-B	100.0	99.9									103	104	70	98
CW_ai	cat3-fused	99.8	99.7	99.6								112	100	77	90
CW_ai	cat3-frame	100.5		98.0								367	385	87	91
CW_ai	overall	100.0	99.7	98.6								140	141	76	96
CY_ai	cat1-A				-0.4	-0.4	-1.9	-1.9	-1.9			112	109	84	104
CY_ai	cat1-B				0.0	0.0	-1.4	-1.4	-1.4			103	104	75	106
CY_ai	cat3-fused				-0.2	-0.2	-2.3	-2.3	-2.3	-2.9		112	101	66	76
CY_ai	cat3-frame				-0.0	-0.0				-4.3		367	384	87	91
CY_ai	overall				-0.2	-0.2	-1.7	-1.7	-1.7	-3.9		140	141	79	101

NOTE — Condition CY metrics reported using Hausdorff PSNR.

Table 2 – Summary performance of octree geometry and RAHT attribute coding using release v11.0 relative to v10.0 results

Condition	Class	BPP Ratio [%]			BD-Rate [$\Delta\%$]						Avg. of ratio maxrssk [%]		Ratio of avg. runtime [%]		
		Geometry	Colour	Refl	D1	D2	Y	Cb	Cr	R	Encoder	Decoder	Encoder	Decoder	
C1_ai	cat1-A				-0.4	-0.4	-7.0	-7.2	-7.3			105	101	98	104
C1_ai	cat1-B				0.0	0.0	-3.7	-4.0	-3.8			102	93	92	101
C1_ai	cat3-fused				-0.2	-0.2	-4.9	-2.8	-2.8	-2.0		90	77	79	83
C1_ai	cat3-frame				-0.0	-0.0				-18.3		367	384	80	82
C1_ai	overall				-0.2	-0.2	-5.3	-5.3	-5.3	-13.4		136	132	92	99
C2_ai	cat1-A				-0.1	-0.1	-5.6	-4.7	-5.3			114	105	105	
C2_ai	cat1-B				-0.1	-0.1	-4.0	-4.9	-4.1			106	96	101	103
C2_ai	cat3-fused				0.1	0.1	-4.3	-2.4	-2.4	-2.5		99	85	100	103
C2_ai	cat3-frame				0.2	0.2				-10.6		104	99	110	125
C2_ai	overall				-0.1	-0.1	-4.7	-4.6	-4.5	-8.2		108	99	104	

Table 3 – Summary performance of trisoup geometry and lifting based attribute coding using release v11.0 relative to v10.0 results, using v10 CTC

Condition	Class	BPP Ratio [%]			BD-Rate [$\Delta\%$]						Avg. of ratio maxrssk [%]		Ratio of avg. runtime [%]		
		Geometry	Colour	Refl	D1	D2	Y	Cb	Cr	R	Encoder	Decoder	Encoder	Decoder	
C2_ai	cat1-A				1.0	-0.7	-8.3	-11.2	-14.1			107	104	90	72
C2_ai	cat1-B				-0.2	-1.0	-4.2	-6.8	-8.9			106	105	92	72
C2_ai	overall				0.4	-0.9	-6.2	-8.9	-11.4			107	104	91	72

Table 4 – Summary performance of trisoup geometry and RAHT attribute coding using release v11.0 relative to v10.0 results, using v10 CTC

Condition	Class	BPP Ratio [%]			BD-Rate [$\Delta\%$]						Avg. of ratio maxrssk [%]		Ratio of avg. runtime [%]		
		Geometry	Colour	Refl	D1	D2	Y	Cb	Cr	R	Encoder	Decoder	Encoder	Decoder	
C2_ai	cat1-A				1.0	-0.7	-7.0	-7.3	-8.0			107	101	105	104
C2_ai	cat1-B				-0.2	-1.0	-4.5	-4.7	-5.3			105	93	105	105
C2_ai	overall				0.4	-0.9	-5.7	-6.0	-6.6			106	97	105	104

⁴[pcc-tmc13-tmc13v11.0-rc1_octree_predlift_vs_tmc13v11.0_octree_predlift.xlsm](#)

⁵[pcc-tmc13-tmc13v11.0-rc1_octree_raht_vs_tmc13v11.0_octree_raht.xlsm](#)

⁶[pcc-tmc13-tmc13v11.0-rc1_trisoup_lift_vs_tmc13v11.0_trisoup_lift.xlsm](#)

⁷[pcc-tmc13-tmc13v11.0-rc1_trisoup_raht_vs_tmc13v11.0_trisoup_raht.xlsm](#)

Cross checking

A cross-check of release v11.0-rc1 was kindly performed by Panasonic and Sony over all CTC configurations (octree, trisoup, RAHT, predlift) and conditions (C1, C2, CW, CX). All cross-checks⁸⁹¹⁰¹¹ 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.

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

Condition	Class	BPP Ratio [%]			D1	D2	BD-Rate [$\Delta\%$]				Avg. of ratio maxrssk [%]		Ratio of avg. runtime [%]	
		Geometry	Colour	Refl			Y	Cb	Cr	R	Encoder	Decoder	Encoder	Decoder
C1_ai	00=attr				0.0	0.0	-5.4	-7.4	-8.9	-6.2	102	104	70	84
C1_ai	01=geom				-0.0	-0.0	-5.4	-7.4	-8.9	-6.3	135	139	65	79
C1_ai	02=hls				-0.1	-0.1	-5.3	-7.1	-8.7	-6.3	135	139	62	80
C1_ai	03=slice				-0.2	-0.2	-5.4	-7.3	-8.8	-6.3	137	139	63	81
C1_ai	tmc13v11.0-rc1				-0.2	-0.2	-5.4	-7.3	-8.8	-6.3	137	139	63	82

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

Condition	Class	BPP Ratio [%]			D1	D2	BD-Rate [$\Delta\%$]				Avg. of ratio maxrssk [%]		Ratio of avg. runtime [%]	
		Geometry	Colour	Refl			Y	Cb	Cr	R	Encoder	Decoder	Encoder	Decoder
C2_ai	00=attr				0.0	0.0	-3.9	-6.2	-9.4	-2.1	101	110	90	74
C2_ai	01=geom				0.0	0.0	-3.9	-6.2	-9.4	-2.1	101	110	88	75
C2_ai	02=hls				-0.1	-0.1	-3.8	-6.1	-9.3	-2.1	101	110	88	
C2_ai	03=slice				-0.1	-0.1	-3.9	-6.1	-9.3	-2.0	109	110	92	
C2_ai	tmc13v11.0-rc1				-0.1	-0.1	-3.9	-6.1	-9.3	-2.0	109	110	91	74

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

Condition	Class	BPP Ratio [%]			D1	D2	BD-Rate [$\Delta\%$]				Avg. of ratio maxrssk [%]		Ratio of avg. runtime [%]	
		Geometry	Colour	Refl			Y	Cb	Cr	R	Encoder	Decoder	Encoder	Decoder
CW_ai	00=attr	100.0	99.7	98.6							104	105	84	100
CW_ai	01=geom	100.0	99.7	98.6							138	141	78	94
CW_ai	02=hls	100.0	99.7	98.6							137	141	76	96
CW_ai	03=slice	100.0	99.7	98.6							140	141	76	96
CW_ai	tmc13v11.0-rc1	100.0	99.7	98.6							140	141	76	96

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

Condition	Class	BPP Ratio [%]			D1	D2	BD-Rate [$\Delta\%$]				Avg. of ratio maxrssk [%]		Ratio of avg. runtime [%]		
		Geometry	Colour	Refl			Y	Cb	Cr	R	Encoder	Decoder	Encoder	Decoder	
C2_ai	00=attr				0.0	0.0	-5.6	-4.8	-5.3			102	107	98	104
C2_ai	01=geom				0.0	0.0	-5.6	-4.8	-5.3			102	107	99	111
C2_ai	02=hls				-0.1	-0.1	-5.6	-4.8	-5.3			102	105	99	108
C2_ai	03=slice				-0.1	-0.1	-5.6	-4.7	-5.3			114	105	109	109
C2_ai	tmc13v11.0-rc1				-0.1	-0.1	-5.6	-4.7	-5.3			114	105	105	

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

Condition	Class	BPP Ratio [%]			D1	D2	BD-Rate [$\Delta\%$]				Avg. of ratio maxrssk [%]		Ratio of avg. runtime [%]		
		Geometry	Colour	Refl			Y	Cb	Cr	R	Encoder	Decoder	Encoder	Decoder	
C2_ai	00=attr				0.0	0.0	-4.1	-5.1	-4.9			102	105	102	104
C2_ai	01=geom				-0.0	-0.0	-4.1	-5.1	-4.9			102	105	100	
C2_ai	02=hls				-0.1	-0.1	-3.9	-5.0	-4.7			101	96	98	103
C2_ai	03=slice				-0.1	-0.1	-4.0	-4.9	-4.1			106	96	101	104
C2_ai	tmc13v11.0-rc1				-0.1	-0.1	-4.0	-4.9	-4.1			106	96	101	103

⁸[report_tmc13v11.0-rc1_octree_predlift_apple_vs_panasonic.txt](#)

⁹[report_tmc13v11.0-rc1_trisoup_predlift_apple_vs_panasonic.txt](#)

¹⁰[report_tmc13v11.0-rc1_octree_raht_apple_vs_panasonic.txt](#)

¹¹[report_tmc13v11.0-rc1_trisoup_raht_apple_vs_panasonic.txt](#)

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

Condition	Class	BPP Ratio [%]			Refl	D1	D2	BD-Rate [Δ]			Cr	R	Avg. of ratio maxrssk [%]		Ratio of avg. runtime [%]	
		Geometry	Colour					Y	Cb				Encoder	Decoder	Encoder	Decoder
C2_ai	00=attr					0.0	0.0	-8.6	-11.5	-14.2			100	104	85	73
C2_ai	01=geom					0.0	0.0	-8.6	-11.5	-14.2			100	104	85	72
C2_ai	02=hls					-0.5	-0.5	-8.4	-11.2	-14.0			101	104	86	73
C2_ai	03=slice					1.0	-0.7	-8.3	-11.2	-14.1			107	104	90	72

Table 11 – List of integration results

Integration	Config	Reference	Reporting workbook
01=attr	All	v10.0	pcc-tmc13-tmc13v10.0+integration01=attr_*.xslm
02=geom	All	01=attr	pcc-tmc13-tmc13v10.0+integration02=geom_*.xslm
03=hls	All	02=geom	pcc-tmc13-tmc13v10.0+integration03=hls_*.xslm
04=slice	All	03=hls	pcc-tmc13-tmc13v10.0+integration04=slice_*.xslm
rc1	All	04=slice	pcc-tmc13-tmc13v11.0-rc1_octree_predlift_vs_{}_tmc13v10.0_octree_predlift.xslm

Integration 1 — Attribute coding

- m52986: replace unary binarisation of zero_run
- m52986: code coefficient values using EGk1
- m54703: exploit impossibility of zero magnitude coeff tuple
- m53672: predict last coefficient component in lifting transform
- m54633: require inter or intra lod prediction
- m53557: add dyadic decomposition to raht
- m54607: threshold neighbours in raht prediction upsampler
- m54668: use look-up tables for lod generation
- m54668: signal separate intra and inter lod search ranges
- m54668: use look-up table hybrid nearest neighbour search
- m54668: use look-up table hybrid scalable neighbour search
- m53613: add xyz to spherical coordinate conversion
- m54698: derive secondary qp from clipped primary qp

Integration 2 — Geometry coding

Octree based geometry coding:

- m53677: move planar and idcm to start of tree node
- m53677: remove planar state from octree node
- m54670: contextualise planar by current neighbourhood
- m54670: contextualise planar w/o relative node position
- m54707: use binary search to find angular laser
- m54694: reduce azimuthal contexts to 8
- m54694: contextualise is_planar by plane orientation
- m52957: implicitly ordered two point idcm
- m52957: add relaxed idcm eligibility constraints
- m54697: use eight qp quantization step size doubling interval
- m54697: configure granularity of qp to step size mapping
- m54624: enable qtbt parametrisation under angular tweak

Predictive tree based geometry coding:

- m53618: sort by (azimuth, r, elevation) in azimuthal sort
- m54592: quantize azimuth when sorting to build tree
- m53618: add in-tree quantisation of prediction residual
- m53618: use quantization based decimation subsampling

m53618: remove sign bit inference in pcm mode
m53618: add angular predictive coding mode
m54674: fix bias in bit estimation
m54674: code residual magnitude msb first
m54628: reduce residual magnitude bins

Integration 3 — High-level syntax and miscellaneous changes

m54705: condition idcm parameters on idcm being enabled
m54705: use minus1 form for lod_neigh_bias, tile_size
m54705: code potentially large ue(v) values using u(ue(v))
m54652: code tile origin and size with independent bit widths
m54652: code explicit ti_tile_id as u(n)
m54652: guard tile inventory body in case of no tiles
m54634: remove redundant neighbour_context_restriction_flag
trisoup: fix decoder where octree may have more nodes than points
trisoup: fix encoder minimum octree node size for small trees
m54713: signal trisoup node size per slice
m54705: prohibit trisoup incompatible octree tools
m54702: linearly predict laser elevation
m54702: differentially code geom_angular_num_phi_per_turn
m54599: permit prediction transform with scalable lods
m52732: add main profile compatibility flag
m51064: add unique point position constraint flag
m53542: add geometry slice entropy continuation
m54659: add attribute slice entropy continuation
attr: fix encoding one too few zero-run lengths in pred transform
hls: tile origin should be relative to inventory origin
m54616: add per octree layer point count metadata
geom: use int8_t to represent geometry qp in octree node
m53723: don't compute intra occupancy prediction unnecessarily

Integration 4 — Slicing

m54651: fix uniform square partitioning crash
m54651: fix incorrect tile count in tile partitioning
m54651: permit more tiles to be generated
m54651: move slice partitioning after tile inventory write out
m54651: use common code path for generating slices
m54651: calculate slice origin immediately prior to each slice

Release v11.0

This release contains the integration of, or aspects relating to: [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, 29, 30, 31, 32, 33, 34, 35, 36]

General comments

- CTC configurations are provided for the following test conditions:
 - octree + pred/lift transforms [C1, C2, CW, CY]
 - octree + RAHT [C1, C2]
 - predgeom + pred/lift transforms [C1, C2, CW, CY]

predgeom + RAHT [C1, C2]
 trisoup + pred/lift transforms [C2]
 trisoup + RAHT [C2]

- The common test conditions for trisoup have been changed. Rate point r06 has been removed since this didn't actually use trisoup. Additionally, the two of the three rate points that used the identical trisoup node size have been changed to resolve issues with reporting results.

The trisoup node sizes are now 1, 2, 3, 4, and 5, compared to the previous range of 0, 2, 3, 3, 3, 4.

When populating the result workbooks with trisoup data, do not enter anything in the r06 row, otherwise various results may be incorrectly calculated.

- 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).
 - the current sequence categorisation does not facilitate identifying the type of content providing compression gains or losses.
- Trisoup now supports per-slice configuration. However, it is unclear if a second GPS is required to set `trisoup_node_size = 0`.
- An issue with trisoup has been identified where some configurations can generate fewer points than trisoup node sizes. For decoders trusting the point count to size the octree fifo, this results in an undecodable stream. A work-around has been implemented in TMC13
- The increase in maxrss for cat3-frame content is due to the conditional initialisation of the child neighbour buffer. Without explicit initialisation, physical backing pages are opportunistically allocated, reducing the measured resident set size.
- 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.

Location of changes between v10.0 and v11.0-rc1

<code>cfg/octree-lifft-ctc-lossless-geom-lossy-attrs.yaml</code>	17 +-
<code>cfg/octree-lifft-ctc-lossy-geom-lossy-attrs.yaml</code>	8 +-
<code>cfg/octree-predt-ctc-lossless-geom-lossless-attrs.yaml</code>	17 +-
<code>cfg/octree-predt-ctc-lossless-geom-nearlossless-attrs.yaml</code>	17 +-
<code>cfg/octree-raht-ctc-lossless-geom-lossy-attrs.yaml</code>	16 +-
<code>cfg/octree-raht-ctc-lossy-geom-lossy-attrs.yaml</code>	7 +-
<code>cfg/trisoup-lifft-ctc-lossy-geom-lossy-attrs.yaml</code>	22 +-
<code>cfg/trisoup-raht-ctc-lossy-geom-lossy-attrs.yaml</code>	22 +-
<code>doc/README.options.md</code>	126 ++++-
<code>doc/mpeg-pcc-tmc13-sw-manual.tex</code>	6 +-
<code>tmc3/Attribute.h</code>	27 +-
<code>tmc3/AttributeCommon.cpp</code>	44 +-
<code>tmc3/AttributeCommon.h</code>	34 +-
<code>tmc3/AttributeDecoder.cpp</code>	279 +++++-----
<code>tmc3/AttributeDecoder.h</code>	11 +-
<code>tmc3/AttributeEncoder.cpp</code>	455 ++++++++-----
<code>tmc3/AttributeEncoder.h</code>	13 +-
<code>tmc3/CMakeLists.txt</code>	4 +-
<code>tmc3/DualLutCoder.cpp</code>	40 +-
<code>tmc3/DualLutCoder.h</code>	1 -

tmc3/OctreeNeighMap.h	4 +-
tmc3/PCCMath.h	94 +++-
tmc3/PCCMisc.h	11 +
tmc3/PCCPointSet.h	13 +-
tmc3/PCCTMC3Common.h	908 ++++++++-----
tmc3/PCCTMC3Decoder.h	22 +-
tmc3/PCCTMC3Encoder.h	25 +-
tmc3/RAHT.cpp	142 ++++--
tmc3/TMC3.cpp	204 ++++---
tmc3/coordinate_conversion.cpp	101 ++++
tmc3/coordinate_conversion.h	65 +++
tmc3/decoder.cpp	120 ++++--
tmc3/encoder.cpp	262 ++++++---
tmc3/entropydirac.h	12 +-
tmc3/entropyutils.h	185 +++-----
tmc3/geometry.h	14 +-
tmc3/geometry_octree.cpp	106 +++--
tmc3/geometry_octree.h	156 ++++--
tmc3/geometry_octree_decoder.cpp	555 ++++++-----
tmc3/geometry_octree_encoder.cpp	709 ++++++-----
tmc3/geometry_params.h	6 +-
tmc3/geometry_predictive.h	133 ++++--
tmc3/geometry_predictive_decoder.cpp	217 ++++++--
tmc3/geometry_predictive_encoder.cpp	394 ++++++-----
tmc3/geometry_trisoup_decoder.cpp	9 +-
tmc3/geometry_trisoup_encoder.cpp	10 +-
tmc3/hls.h	133 ++++--
tmc3/io_hls.cpp	660 ++++++-----
tmc3/io_hls.h	12 +-
tmc3/partitioning.cpp	63 ++-
tmc3/partitioning.h	7 +-
tmc3/pointset_processing.cpp	104 +++-
tmc3/pointset_processing.h	29 +-
tmc3/quantization.cpp	14 +-
tmc3/quantization.h	14 +-
tmc3/tables.cpp	149 ++++++
tmc3/tables.h	5 +

57 files changed, 4920 insertions(+), 1913 deletions(-)

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