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Title: G-PCC: A method to compute dist2 values for LoD attribute coding
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Abstract

Geometry-based point cloud compression uses a set of parameters for level-of-detail (LoD) generation. The LoDs are used for both the prediction-based and lifting-based attribute coding schemes. So far, the LoD generation parameters used in the G-PCC common test conditions are determined manually, finding the best parameters through either an exhaustive search or binary search. Each point cloud is compressed/decompressed multiple times for different set of parameters. The Rate-Distortion (RD) performance obtained with each set of parameters is computed and the one leading to the best RD compromise is selected.

In this contribution, we propose a low complexity and fully automatic non-normative technique to compute the LoD generation parameters with competitive RD performance. The effect of this is to enable LoD attribute coding for all content categories without any manual tuning.

LoD determination

Rather than black magic, the general principle for choosing a dist2 value for LoD attribute coding is to obtain a ratio of 1:4 in the number of points in the finest and second finest levels of detail. The current dist2 values were initially determined in a response to the call for proposals. For new test sequences the dist2 values (which was originally a more cumbersome list) were copied from similar looking test sequences with little regard to correctness. At the previous meeting, we proposed updated dist2 values based upon a manual search for ideal values [1].

A starting point

The LoD subsampling scheme is a form of down-sampler. It requires a squared distance value to workout the subsampling ratios. The octree that is used to encode the point cloud is also a form of downsampler. It down-samples by factors of 2 in each direction for each level of the octree.

A starting point for the method is to use information that can be discovered during octree coding to approximate an octree level that results in a ratio of one quarter of the total points. This assumes a uniform density where, eventually, surface-like structures are discovered and down-sampled. Since in reality this is unlikely to happen at the exact transition between two octree levels, the squared distance for LoD subsamping is derived by linearly interpolating between the levels either side of the transition. Figure 1 shows the ratio of points in each octree level for various sequences.

The specific process is as follows:

1. Let lvl_n be the number of unique points in the n-th lowest octree level. lvl_0 represents the number of unique points in the source point cloud.

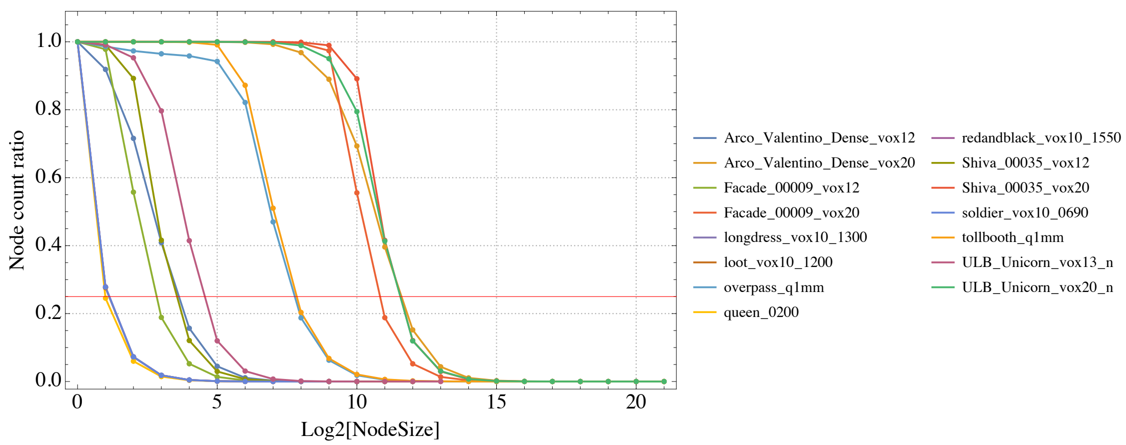

Figure 1 – Plot of per level count of octree nodes as ratio to leaf node count

2. Let $\text{lvlRatio}_n = \text{lvl}_n \,/\, \text{lvl}_0$ as the ratio of unique points at the n-th level to the number of unique points in the source.
3. Find the smallest a that fulfils $\text{lvlRatio}_a > ¼$.
4. Linearly interpolate between the values of lvlRatio_a and lvlRatio_{a+1} to determine the value of x_0 at $y = ¼$:

$$x_0 = \frac{¼ - \text{lvlRatio}_a}{\text{lvlRatio}_{a+1} - \text{lvlRatio}_a} + a + 1$$

5. Determine the squared distance as $d_i = \lceil 4^{x_i - 1} \rceil$.

Refinement

While the base method provides a reasonable approximation, it does not always yield the desired ratio. The squared distance value may be refined by iterative interpolations as follows for slightly better RD-performance at the cost of increased computational effort.

Starting with $i = 0$,

1. Perform LoD subsampling of the points using the squared distance $d_i = \lceil 4^{x_i - 1} \rceil$ to determine the true ratio, lodRatio_{x_i} of points for the finest LoD.
2. Linearly interpolate as follows:

$$x_{i+1} = \begin{cases} \frac{(¼ - \text{lodRatio}_{x_i})(a - x_i)}{\text{lvlRatio}_a - \text{lodRatio}_{x_i}} + a & \text{if } \text{lodRatio}_{x_0} < ¼ \\ \frac{(¼ - \text{lvlRatio}_{a+1})(x_i - (a+1))}{\text{lodRatio}_{x_i} - \text{lvlRatio}_{a+1}} + x_i & \text{otherwise} \end{cases}$$

3. Repeat with successive values if i until either of the following conditions reached:
   - lodRatio_{x_i} is very close to ¼, i.e. $\|\text{lodRatio}_{x_i} - ¼\| \leq \epsilon$.
   - Successive values of d_i have converged. This is possible because d_i is an integer.
4. Use d_i from the final iteration as dist2 for LoD generation.

Implementation remarks

While the proposed method is capable of using data obtained during octree coding, it is currently implemented as an independent preprocess that occurs at the start of encoding a point cloud. The derived dist2 values are sent in the APS, overriding anything specified on the codec command line.

Results

Tables 1 and 2 show the performance of the both approaches according to the common test conditions [2] and relative to the anchor results for TMC13v8.0 [3].

Table 1 – Comparison of the unrefined approach compared to TMC13v8.0

		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						1.1	1.9	2.3		114	100	112	100
C1_ai	cat1-B													
C1_ai	cat3-fused						0.0	0.0	0.0	0.0	118	100	112	102
C1_ai	cat3-frame									0.0	102	100	113	95
C1_ai	overall						0.9!	1.7!	2.0!	0.0	112	100	198	177
C2_ai	cat1-A				0.0	0.0	−2.4	−5.2	−4.5		103	98	99	75
C2_ai	cat1-B				0.0	0.0					115	147	243	227
C2_ai	cat3-fused				0.0	0.0	0.0	0.0	0.0	0.0	106	100	103	102
C2_ai	cat3-frame				0.0	0.0				0.0	102	100	102	97
C2_ai	overall				0.0	0.0	−2.1!	−4.5!	−3.9!	0.0	108	120	146	126
CW_ai	cat1-A	100.0	99.9								115	100	107	103
CW_ai	cat1-B	100.0									141	131	157	153
CW_ai	cat3-fused	100.0	100.0	100.0							118	100	112	98
CW_ai	cat3-frame	100.0		100.0							102	100	117	95
CW_ai	overall	100.0	108.9!	100.0							125	113	128	120
CY_ai	cat1-A						−1.1	−1.1	−1.1		115	100	109	99
CY_ai	cat1-B													
CY_ai	cat3-fused						0.0	0.0	0.0	0.0	118	100	104	94
CY_ai	cat3-frame									0.0	102	100	124	101
CY_ai	overall						−1.0!	−1.0!	−1.0!	0.0	112	100	197	176

NOTE — Condition CY metrics reported using Hausdorff PSNR.

Table 2 – Comparison of the refined approach compared to TMC13v8.0

		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						0.4	0.6	0.9		118	100	135	97
C1_ai	cat1-B													
C1_ai	cat3-fused						0.0	0.0	0.0	0.0	127	100	149	102
C1_ai	cat3-frame									0.0	102	100	163	103
C1_ai	overall						0.3!	0.6!	0.8!	0.0	115	100	258	175
C2_ai	cat1-A				0.0	0.0	−2.6	−5.2	−4.5		103	98	101	74
C2_ai	cat1-B				0.0	0.0					117	147	271	224
C2_ai	cat3-fused				0.0	0.0	0.0	0.0	0.0	0.0	107	100	111	100
C2_ai	cat3-frame				0.0	0.0				0.0	102	100	112	97
C2_ai	overall				0.0	0.0	−2.3!	−4.6!	−4.0!	0.0	109	120	157	125
CW_ai	cat1-A	100.0	100.0								119	100	126	103
CW_ai	cat1-B	100.0									160	131	219	153
CW_ai	cat3-fused	100.0	100.0	100.0							127	100	168	91
CW_ai	cat3-frame	100.0		100.0							103	100	156	95
CW_ai	overall	100.0	108.9!	100.0							135	113	167	120
CY_ai	cat1-A						−0.3	−0.3	−0.3		119	100	131	99
CY_ai	cat1-B													
CY_ai	cat3-fused						0.0	0.0	0.0	0.0	127	100	150	100
CY_ai	cat3-frame									0.0	103	100	173	104
CY_ai	overall						−0.3!	−0.3!	−0.3!	0.0	116	100	255	175

NOTE — Condition CY metrics reported using Hausdorff PSNR.

References

[1] Z. Gao, D. Flynn, and K. Mammou, "[G-PCC] [New proposal] Improved encode parameters for Lifting attribute coding." ISO/IEC JTC1/SC29/WG11, 128th meeting, Geneva, Tech. Rep. m51008, Oct. 2019.

[2] 3DG, "Common Test Conditions for PCC," ISO/IEC JTC1/SC29/WG11, 128th meeting, Geneva, Tech. Rep. w18883, Oct. 2019.

[3] ——, "G-PCC performance evaluation and anchor results," ISO/IEC JTC1/SC29/WG11, 128th meeting, Geneva, Tech. Rep. w18885, Oct. 2019.