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Title: G-PCC: Integer step sizes for in-tree geometry quantisation
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Abstract

In-tree geometry scaling [1, m49232] provides a means to quantise (encoder) and scale (decoder) geometry positions in a non-uniform manner, even while the coding tree is being constructed. In the current draft text scaling is defined to use a quantisation step size as an exponential function of a quantisation parameter, similar to attribute coding.

The derivation results in fixed-point step sizes that, when used to reconstruct integer point positions, result in objectionable banding of dense objects without further post processing.

This contribution suggests an alternative derivation of the quantisation step size that results in integer step sizes.

Non-integer step sizes

In core experiment 13.29 [2] on geometry quantisation, it is observed that when applied to dense point clouds the use of fixed-point step sizes results in observable banding in reconstructed point positions [3]. The only remedy in this case is to perform correct rescaling, or to employ a method to fill in holes. Figure 1 illustrates this effect using QP=11. Table 1 shows the quantisation step sizes and the resulting quantised node sizes (which must be rescaled back to the original node size during reconstruction).

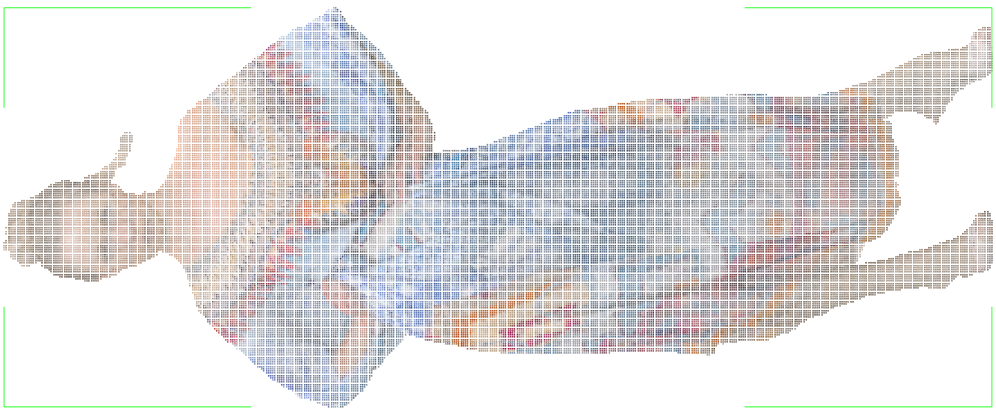

Figure 1 – Longdress with QP=11, orthographic projection

Table 1 – Effect of quantisation step size on node sizes

		Node size								
qP	qS	1	2	4	8	16	32	64	128	256
4	1	1	2	4	8	16	32	64	128	256
5	1.12112	1	1.78394	3.56787	7.13574	14.27149	28.54297	57.08594	114.17189	228.34377
6	1.25779	1	1.59009	3.18018	6.36035	12.72071	25.44142	50.88284	101.76567	203.53135
7	1.41406	1	1.41437	2.82874	5.65747	11.31495	22.6299	45.25979	90.51958	181.03916
8	1.58591	1	1.26111	2.52222	5.04443	10.08886	20.17773	40.35546	80.71091	161.42183
9	1.78126	1	1.1228	2.2456	4.49121	8.98242	17.96484	35.92967	71.85934	143.71868
10	2	1	1	2	4	8	16	32	64	128
11	2.24223	1	1	1.78394	3.56787	7.13574	14.27149	28.54297	57.08594	114.17189
12	2.51558	1	1	1.59009	3.18018	6.36035	12.72071	25.44142	50.88284	101.76567
13	2.82812	1	1	1.41437	2.82874	5.65747	11.31495	22.6299	45.25979	90.51958
14	3.17181	1	1	1.26111	2.52222	5.04443	10.08886	20.17773	40.35546	80.71091
15	3.56252	1	1	1.1228	2.2456	4.49121	8.98242	17.96484	35.92967	71.85934
16	4	1	1	1	2	4	8	16	32	64
17	4.48447	1	1	1	1.78394	3.56787	7.13574	14.27149	28.54297	57.08594
18	5.03117	1	1	1	1.59009	3.18018	6.36035	12.72071	25.44142	50.88284
19	5.65623	1	1	1	1.41437	2.82874	5.65747	11.31495	22.6299	45.25979
20	6.34363	1	1	1	1.26111	2.52222	5.04443	10.08886	20.17773	40.35546
21	7.12503	1	1	1	1.1228	2.2456	4.49121	8.98242	17.96484	35.92967
22	8	1	1	1	1	2	4	8	16	32
23	8.96893	1	1	1	1	1.78394	3.56787	7.13574	14.27149	28.54297
24	10.06233	1	1	1	1	1.59009	3.18018	6.36035	12.72071	25.44142
25	11.31247	1	1	1	1	1.41437	2.82874	5.65747	11.31495	22.6299
26	12.68726	1	1	1	1	1.26111	2.52222	5.04443	10.08886	20.17773
27	14.25006	1	1	1	1	1.1228	2.2456	4.49121	8.98242	17.96484
28	16	1	1	1	1	1	2	4	8	16
29	17.93787	1	1	1	1	1	1.78394	3.56787	7.13574	14.27149
30	20.12466	1	1	1	1	1	1.59009	3.18018	6.36035	12.72071
31	22.62494	1	1	1	1	1	1.41437	2.82874	5.65747	11.31495
32	25.37451	1	1	1	1	1	1.26111	2.52222	5.04443	10.08886
33	28.50012	1	1	1	1	1	1.1228	2.2456	4.49121	8.98242
34	32	1	1	1	1	1	1	2	4	8

Proposal

It is proposed to replace the quantisation step size derivation function with the following:

$$\mathrm{qS} = \frac{1}{4}\left(4 + (\mathrm{QP} \mod 4)\right) \times 2^{\left\lfloor \frac{\mathrm{QP}}{4} \right\rfloor} \tag{1}$$

This results in the step size series of 1, 1.25, 1.5, 1.75, 2, 2.5, 3, 3.5, 4, 5, 6, 7, 8, 10, 12, 14, 16, 20, 24, 28, 32, 40, 48, 56, 64, 80, 96, 112, 128, 160, 192, 224, 256, 320, 384, 448, 512, 640, 768, 896, 1024, ….

Only QPs 1, 2, 3, 5, and 7 result in non-integer powers of two. This is necessary to maintain the simple derivation. The minimum value of QP is 0 (qS = 1).

This is implemented in the TM as follows:

```
 QuantizerGeom(int qp)
 {
-    int qpShift = qp / 6;
-    _stepSize = kQpStep[qp % 6] << qpShift;
-    _stepSizeRecip = kQpStepRecip[qp % 6] >> qpShift;
+    int qpShift = qp / 4;
+    _stepSize = (4 + (qp % 4)) << qpShift;
+    _stepSizeRecip = kQpStepRecip[qp % 4] >> qpShift;
 }
```

…

```
 QuantizerGeom::scale(int64_t x) const
 {
-  return (x * _stepSize + _offset) >> _shift;
+  return x * _stepSize >> 2;
 }
```

Comparison to CE13.29

In order to evaluate the behaviour of the new mapping, the CE study [3] is repeated using the new mapping. Figures 2 and 3 show the rate-distortion behaviour of the new scheme relative to the CE study.

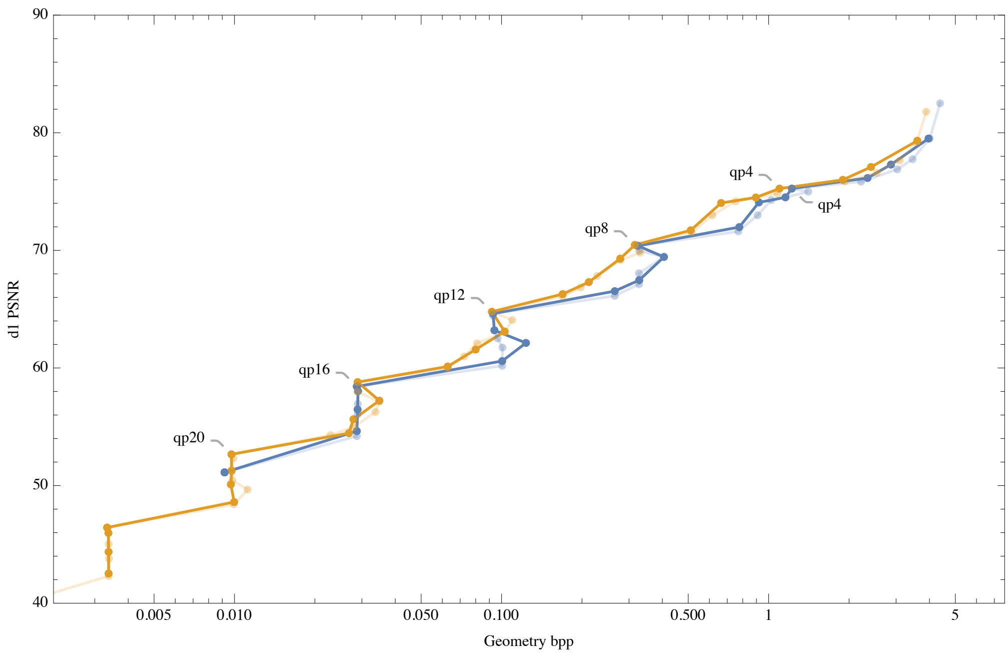

Figure 2 – loot_viewdep_vox12

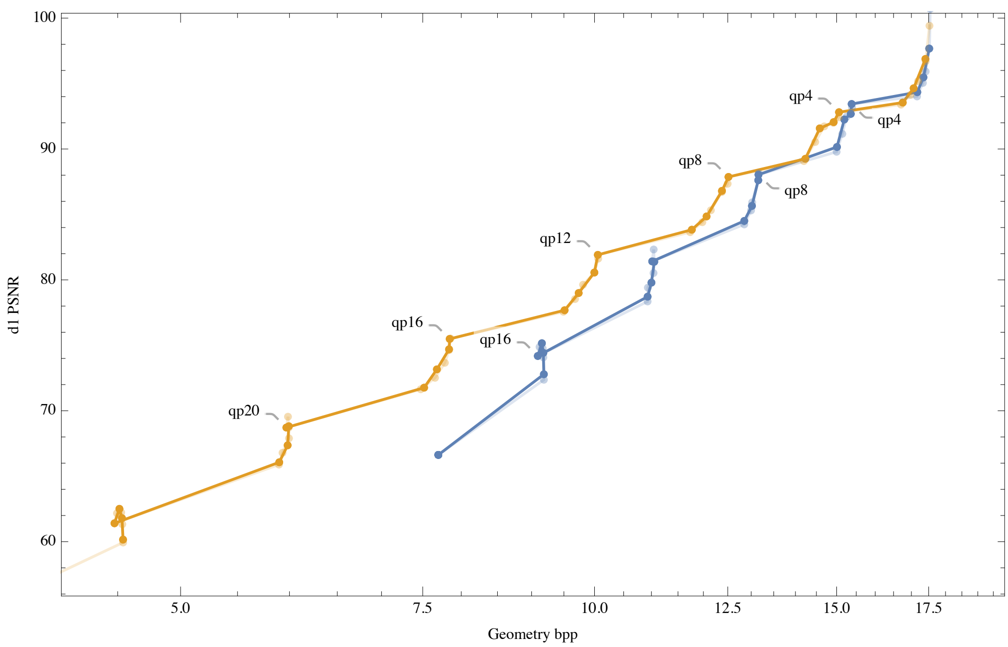

Figure 3 – qnxadas-junction-approach

References

[1] X. Zhang, W. Gao, S. Yea, and S. Liu, "[G-PCC][New proposal] Signaling delta QPs for adaptive geometry quantization in point cloud coding," ISO/IEC JTC1/SC29/WG11, 127th meeting, Gothenburg, Tech. Rep. m49232, Jul. 2019.

[2] 3DG, "CE 13.29 Geometry Quantization QP control," ISO/IEC JTC1/SC29/WG11, 128th meeting, Geneva, Tech. Rep. w18936, Oct. 2019.

[3] D. Flynn and K. Mammou, “G-PCC CE13.29 report on in-loop geometry quantisation,” ISO/IEC JTC1/SC29/WG11, 129th meeting, Brussels, Tech. Rep. m52517, Jan. 2020.