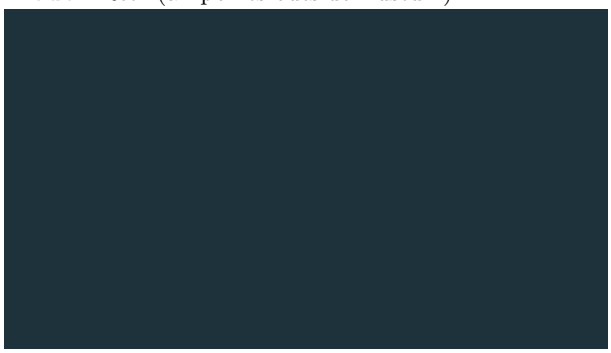
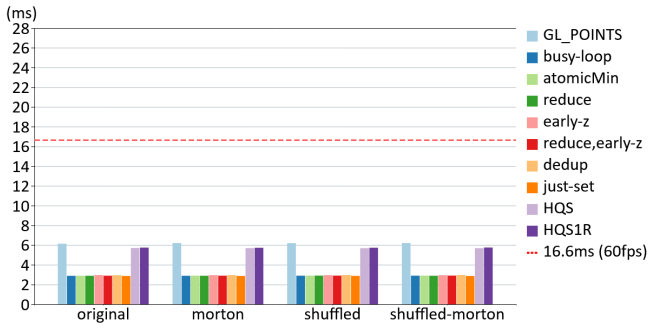
Appendix A: Illustrated Benchmarks

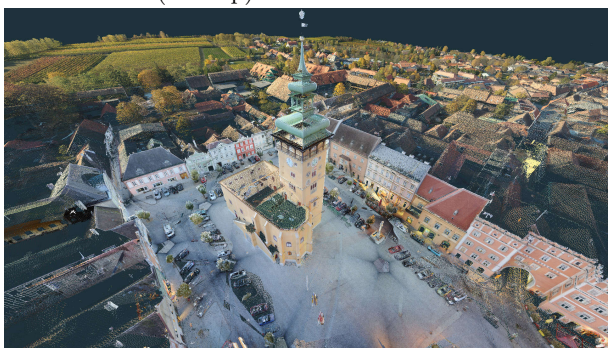
Model: Retz (all points outside frustum)



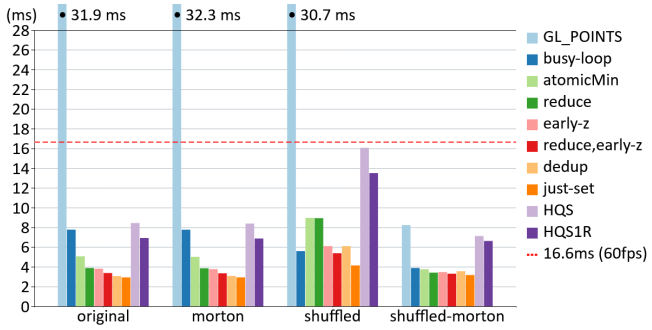
Points: 145 million (2.3GB)



Model: Retz (closeup)



Points: 145 million (2.3GB)



Model: Retz (overview)

Points: 145 million (2.3GB)

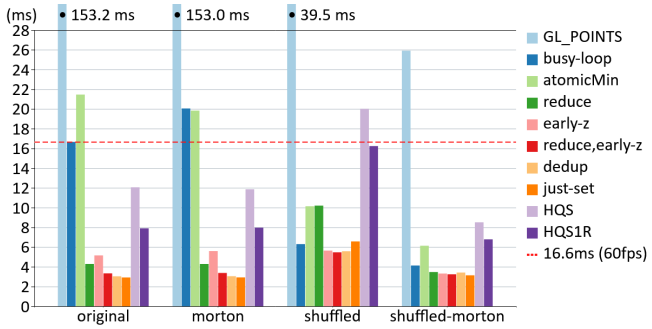


Table 3: *Frame times (ms) for Retz in three different viewpoints on an RTX 3090 (lower is better).* `GL_POINTS` *and atomicMin are strongly affected by the viewpoint, while the combinations of reduce and either early-z or dedup are highly robust to changes of the viewpoint.*

Appendix B: Detailed Benchmark Results

The following tables report the frame times for various models rendered on different GPUs using several methods. The fastest frame times in a row and methods within 5% of the fastest are highlighted in dark green, and methods within 10% of the fastest are highlighted in light green. All times in milliseconds. The set method is exempt from the calculations as it is not a practicable solution.

The results are discussed in Section 5.

Model (#Points)	Vertex Order	GL	Basic Compute					Misc		High-Quality	
			atomicMin	reduce	early-z	reduce, early-z	dedup	busy loop	set	HQS	HQS1R
Lion (4M)	original	0.59	0.28	0.28	0.30	0.30	0.30	0.58	0.25	0.53	0.52
	Morton	0.70	0.27	0.25	0.27	0.27	0.24	0.46	0.21	0.48	0.47
	shuffled	1.34	0.35	0.35	0.32	0.32	0.32	0.35	0.27	0.89	0.65
	shuffled Morton	0.47	0.28	0.26	0.27	0.27	0.26	0.38	0.21	0.48	0.48
Lifeboat (47M)	original	9.19	1.93	1.71	1.29	1.27	1.23	2.62	1.07	2.82	2.45
	Morton	12.29	2.14	1.60	1.50	1.30	1.13	3.35	1.06	2.91	2.56
	shuffled	15.00	5.16	5.14	2.64	2.52	2.61	2.42	1.82	7.25	5.67
	shuffled Morton	5.03	1.65	1.38	1.27	1.26	1.24	2.06	1.14	2.56	2.48
Retz (145M)	original	31.98	5.07	3.91	3.81	3.36	3.07	7.66	2.93	8.40	6.87
	Morton	32.05	5.01	3.86	3.76	3.35	3.06	7.65	2.93	8.36	6.83
	shuffled	30.57	8.58	8.70	6.10	5.35	5.93	5.55	4.24	16.23	13.18
	shuffled Morton	8.22	3.75	3.39	3.46	3.31	3.44	3.84	3.18	7.08	6.61
Endeavor (796M)	original	71.62	26.13	25.79	19.14	17.86	19.00	21.16	20.17	40.35	37.27
	Morton	131.49	36.09	21.53	16.56	15.86	15.26	22.84	15.05	35.34	31.57
	shuffled	162.37	43.11	44.13	28.72	25.62	27.93	24.30	22.09	54.06	50.51
	shuffled Morton	35.62	17.84	16.62	17.68	16.20	18.01	16.56	16.23	31.50	31.46

Table 4: *Frame times (ms) of four models using several different rendering methods. GPU:* ***RTX 3090****. This table is basis for the charts in Table 1.*

Model (Viewpoint)	Vertex Order	GL	Basic Compute					Misc		High-Quality	
			atomicMin	reduce	early-z	reduce, early-z	dedup	busy loop	set	HQS	HQS1R
Retz (no point in frustum)	original	6.13	2.89	2.89	2.96	2.89	2.95	2.88	2.87	5.70	5.74
	Morton	6.20	2.90	2.89	2.95	2.89	2.96	2.89	2.87	5.69	5.73
	shuffled	6.19	2.90	2.90	2.95	2.90	2.96	2.89	2.88	5.68	5.73
	shuffled Morton	6.21	2.90	2.89	2.95	2.90	2.97	2.90	2.87	5.69	5.75
Retz (closeup)	original	31.95	5.07	3.88	3.81	3.37	3.06	7.76	2.92	8.43	6.91
	Morton	32.26	5.01	3.85	3.76	3.34	3.07	7.76	2.93	8.38	6.86
	shuffled	30.71	8.95	8.93	6.10	5.37	6.09	5.59	4.13	16.06	13.50
	shuffled Morton	8.22	3.75	3.41	3.46	3.30	3.55	3.88	3.16	7.12	6.62
Retz (overview)	original	153.22	21.45	4.29	5.15	3.33	3.04	16.66	2.92	12.06	7.90
	Morton	152.96	19.83	4.28	5.59	3.37	3.05	20.05	2.92	11.85	7.97
	shuffled	39.52	10.14	10.20	5.64	5.47	5.57	6.30	6.57	20.01	16.23
	shuffled Morton	25.90	6.13	3.47	3.32	3.24	3.42	4.13	3.14	8.51	6.78

Table 5: *Frame times (ms) of the Retz model (145M points) in three different viewpoints on an* ***RTX 3090****. This table is basis for the charts in Table 3.*

Model (#Points)	Vertex Order	GL	Basic Compute					Misc		High-Quality	
			atomicMin	reduce	early-z	reduce, early-z	dedup	busy loop	set	HQS	HQS1R
Lion (4M)	original	0.78	0.51	0.50	0.53	0.52	0.54	0.92	0.37	0.90	0.93
	Morton	1.10	0.52	0.46	0.48	0.46	0.44	0.82	0.35	0.87	0.89
	shuffled	1.85	1.12	1.12	0.82	0.72	0.72	0.87	0.45	2.61	2.11
	shuffled Morton	0.85	0.55	0.51	0.50	0.49	0.49	0.79	0.38	0.93	0.99
Lifeboat (47M)	original	11.26	3.66	3.11	2.49	2.47	2.44	4.33	2.11	5.21	4.72
	Morton	16.57	4.43	3.21	3.12	2.70	2.36	6.01	2.10	5.52	4.98
	shuffled	21.68	22.26	22.96	9.67	9.22	9.93	7.82	8.50	22.83	20.70
	shuffled Morton	8.96	4.28	3.39	3.00	3.00	2.98	5.02	2.62	5.91	5.89
Retz (145M)	original	42.10	9.73	7.50	7.93	7.00	6.33	13.83	5.89	15.75	13.50
	Morton	42.80	9.71	7.48	7.91	6.92	6.31	13.79	5.90	15.89	13.50
	shuffled	45.63	37.55	38.73	18.30	18.73	17.90	16.15	16.53	51.23	44.32
	shuffled Morton	16.16	9.20	8.14	7.70	7.65	7.60	9.25	7.29	15.81	15.43

Table 6: *Frame times (ms) using several different rendering methods on an **RTX 2070**.*

Model (#Points)	Vertex Order	GL	Basic Compute					Misc		High-Quality	
			atomicMin	reduce	early-z	reduce, early-z	dedup	busy loop	set	HQS	HQS1R
Lion (4M)	original	2.08	1.13	1.15	1.18	1.16	1.72	1.87	1.00	2.11	2.23
	Morton	2.53	1.13	1.05	1.09	1.06	1.13	1.81	0.81	2.09	2.13
	shuffled	4.89	4.60	4.61	3.09	3.00	3.32	3.59	1.89	8.33	7.51
	shuffled Morton	2.16	1.29	1.21	1.16	1.15	1.24	1.71	0.87	2.33	2.37
Lifeboat (47M)	original	24.17	7.76	7.14	6.13	6.09	9.84	9.29	5.61	12.48	11.95
	Morton	34.05	8.60	6.92	6.97	6.42	6.62	13.05	5.11	13.50	12.47
	shuffled	84.06	62.45	63.04	32.07	31.01	35.68	30.14	26.00	67.58	68.03
	shuffled Morton	23.66	9.21	8.04	7.11	7.23	7.70	11.03	5.85	14.03	14.51

Table 7: *Frame times (ms) using several different rendering methods on a **GTX 1060 (3GB)**.*

Model (#Points)	Vertex Order	GL
Lion	original	2.17
	Morton	3.06
	shuffled	2.14
	shuffled Morton	1.85
Lifeboat	original	42.05
	Morton	56.00
	shuffled	18.57
	shuffled Morton	20.01
Retz	original	102.72
	Morton	102.82
	shuffled	37.25
	shuffled Morton	37.62
Retz - overview	original	267.26
	Morton	268.23
	shuffled	53.98
	shuffled Morton	60.14

Table 8: *Frame times (ms) on a **Radeon RX Vega 64 (8GB)**. Only `GL_POINTS` in various vertex orders was evaluated; compute approaches were omitted due to the lack of 64 bit atomic integer operations.*

Appendix C: High-Quality Rendering Visual Comparison

Below, we provide visual comparisons of rendering tested scenes with and without the high-quality antialiasing shaders.

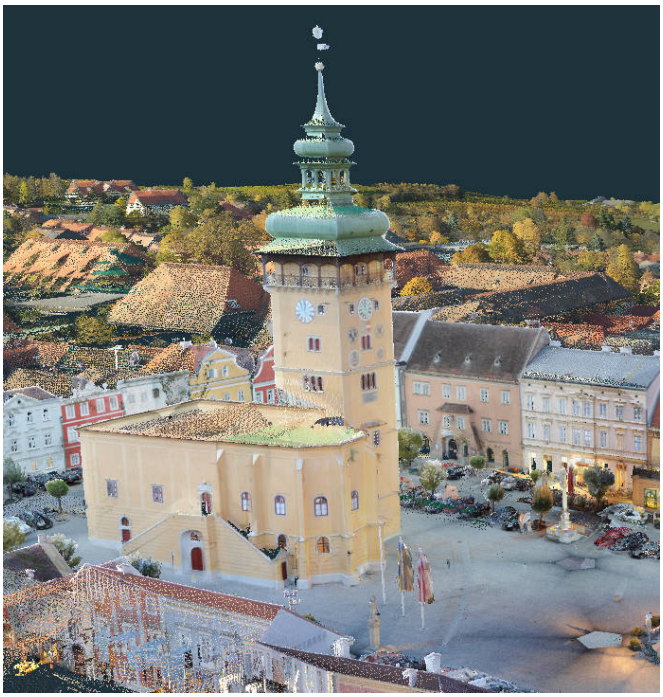
(a) *Lion statue with close-up inset, rendered with* `GL_POINTS`

(b) *Lion statue with close-up inset, rendered with* ***HQS1R***

(a) *Lifeboat with close-up inset, rendered with* `GL_POINTS`

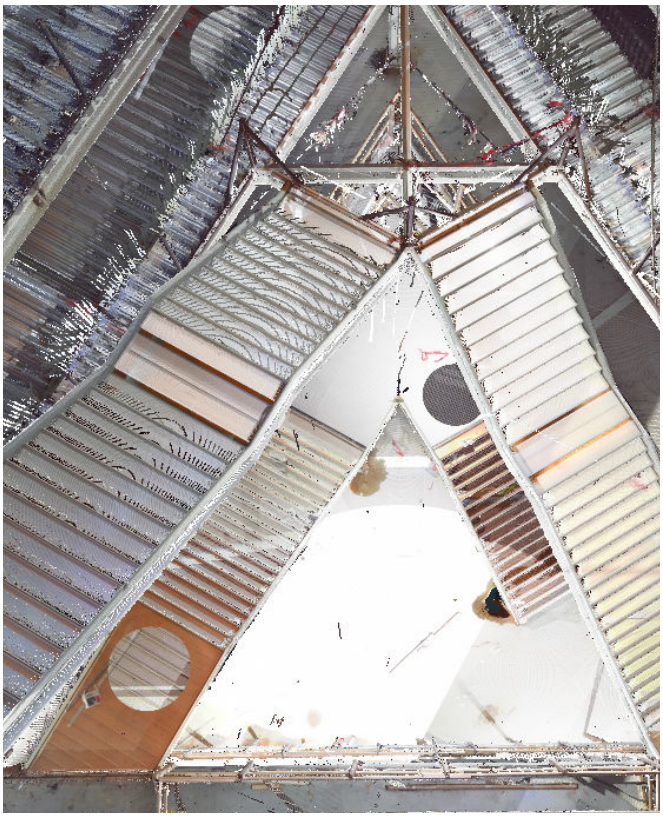
(b) *Lifeboat with close-up inset, rendered with* ***HQS1R***

(a) *Retz, rendered with* `GL_POINTS`



(b) *Retz, rendered with* ***HQS1R***

(a) *Endeavor staircase, rendered with* `GL_POINTS`



(b) *Endeavor staircase, rendered with* ***HQS1R***