

TABLE I
MPPI METHOD OPTIMIZATION TIMES AT VARIOUS NUMBER OF SAMPLES ON VARIOUS HARDWARE

CPU	GPU	Samples	Method	Avg. Time [ms]	CPU	GPU	Samples	Method	Avg. Time [ms]
Intel 13900K	1060 6GB	128	MPPI-Generic	0.180 ± 0.035	Intel 13900K	1080 Ti	128	MPPI-Generic	0.179 ± 0.029
Intel 13900K	1060 6GB	128	autorally	0.436 ± 0.054	Intel 13900K	1080 Ti	128	autorally	0.44 ± 0.12
Intel 13900K	1060 6GB	128	torchrl	24.6 ± 1.6	Intel 13900K	1080 Ti	128	torchrl	24.6 ± 1.8
Intel 13900K	1060 6GB	256	MPPI-Generic	0.191 ± 0.031	Intel 13900K	1080 Ti	256	MPPI-Generic	0.184 ± 0.029
Intel 13900K	1060 6GB	256	autorally	0.432 ± 0.037	Intel 13900K	1080 Ti	256	autorally	0.439 ± 0.036
Intel 13900K	1060 6GB	256	torchrl	28.4 ± 1.4	Intel 13900K	1080 Ti	256	torchrl	28.4 ± 1.4
Intel 13900K	1060 6GB	512	MPPI-Generic	0.226 ± 0.031	Intel 13900K	1080 Ti	512	MPPI-Generic	0.201 ± 0.031
Intel 13900K	1060 6GB	512	autorally	0.434 ± 0.039	Intel 13900K	1080 Ti	512	autorally	0.442 ± 0.038
Intel 13900K	1060 6GB	512	torchrl	28.6 ± 1.6	Intel 13900K	1080 Ti	512	torchrl	28.4 ± 1.6
Intel 13900K	1060 6GB	1024	MPPI-Generic	0.310 ± 0.035	Intel 13900K	1080 Ti	1024	MPPI-Generic	0.220 ± 0.030
Intel 13900K	1060 6GB	1024	autorally	0.467 ± 0.043	Intel 13900K	1080 Ti	1024	autorally	0.448 ± 0.038
Intel 13900K	1060 6GB	1024	torchrl	28.4 ± 1.7	Intel 13900K	1080 Ti	1024	torchrl	28.5 ± 1.6
Intel 13900K	1060 6GB	2048	MPPI-Generic	0.479 ± 0.039	Intel 13900K	1080 Ti	2048	MPPI-Generic	0.298 ± 0.033
Intel 13900K	1060 6GB	2048	autorally	0.545 ± 0.067	Intel 13900K	1080 Ti	2048	autorally	0.482 ± 0.041
Intel 13900K	1060 6GB	2048	torchrl	28.6 ± 1.5	Intel 13900K	1080 Ti	2048	torchrl	28.7 ± 1.4
Intel 13900K	1060 6GB	4096	MPPI-Generic	0.890 ± 0.054	Intel 13900K	1080 Ti	4096	MPPI-Generic	0.432 ± 0.040
Intel 13900K	1060 6GB	4096	autorally	0.986 ± 0.078	Intel 13900K	1080 Ti	4096	autorally	0.549 ± 0.042
Intel 13900K	1060 6GB	4096	torchrl	29.3 ± 1.7	Intel 13900K	1080 Ti	4096	torchrl	28.9 ± 1.7
Intel 13900K	1060 6GB	6144	autorally	1.143 ± 0.077	Intel 13900K	1080 Ti	6144	autorally	0.619 ± 0.041
Intel 13900K	1060 6GB	6144	MPPI-Generic	1.311 ± 0.063	Intel 13900K	1080 Ti	6144	MPPI-Generic	0.702 ± 0.046
Intel 13900K	1060 6GB	6144	torchrl	30.9 ± 1.7	Intel 13900K	1080 Ti	6144	torchrl	29.2 ± 1.7
Intel 13900K	1060 6GB	8192	autorally	1.599 ± 0.071	Intel 13900K	1080 Ti	8192	autorally	0.695 ± 0.047
Intel 13900K	1060 6GB	8192	MPPI-Generic	1.755 ± 0.070	Intel 13900K	1080 Ti	8192	MPPI-Generic	1.109 ± 0.058
Intel 13900K	1060 6GB	8192	torchrl	31.7 ± 1.4	Intel 13900K	1080 Ti	8192	torchrl	29.7 ± 1.5
Intel 13900K	1060 6GB	16384	autorally	3.05 ± 0.64	Intel 13900K	1080 Ti	16384	autorally	1.334 ± 0.061
Intel 13900K	1060 6GB	16384	MPPI-Generic	3.337 ± 0.099	Intel 13900K	1080 Ti	16384	MPPI-Generic	2.188 ± 0.078
Intel 13900K	1060 6GB	16384	torchrl	41.3 ± 1.6	Intel 13900K	1080 Ti	16384	torchrl	33.8 ± 1.6
Intel 13900K	2080	128	MPPI-Generic	0.166 ± 0.023	Intel 13900K	4090	128	MPPI-Generic	0.123 ± 0.032
Intel 13900K	2080	128	autorally	0.29 ± 0.14	Intel 13900K	4090	128	autorally	0.198 ± 0.039
Intel 13900K	2080	128	torchrl	24.8 ± 1.6	Intel 13900K	4090	128	torchrl	24.5 ± 1.6
Intel 13900K	2080	256	MPPI-Generic	0.171 ± 0.024	Intel 13900K	4090	256	MPPI-Generic	0.122 ± 0.029
Intel 13900K	2080	256	autorally	0.292 ± 0.028	Intel 13900K	4090	256	autorally	0.196 ± 0.029
Intel 13900K	2080	256	torchrl	28.6 ± 1.3	Intel 13900K	4090	256	torchrl	28.2 ± 1.3
Intel 13900K	2080	512	MPPI-Generic	0.180 ± 0.028	Intel 13900K	4090	512	MPPI-Generic	0.124 ± 0.026
Intel 13900K	2080	512	autorally	0.299 ± 0.032	Intel 13900K	4090	512	autorally	0.197 ± 0.028
Intel 13900K	2080	512	torchrl	28.7 ± 1.5	Intel 13900K	4090	512	torchrl	28.2 ± 1.6
Intel 13900K	2080	1024	MPPI-Generic	0.204 ± 0.028	Intel 13900K	4090	1024	MPPI-Generic	0.131 ± 0.025
Intel 13900K	2080	1024	autorally	0.302 ± 0.028	Intel 13900K	4090	1024	autorally	0.202 ± 0.025
Intel 13900K	2080	1024	torchrl	28.8 ± 1.5	Intel 13900K	4090	1024	torchrl	28.1 ± 1.6
Intel 13900K	2080	2048	MPPI-Generic	0.261 ± 0.026	Intel 13900K	4090	2048	MPPI-Generic	0.146 ± 0.036
Intel 13900K	2080	2048	autorally	0.323 ± 0.033	Intel 13900K	4090	2048	autorally	0.214 ± 0.035
Intel 13900K	2080	2048	torchrl	28.8 ± 1.3	Intel 13900K	4090	2048	torchrl	28.2 ± 1.3
Intel 13900K	2080	4096	MPPI-Generic	0.398 ± 0.034	Intel 13900K	4090	4096	MPPI-Generic	0.170 ± 0.030
Intel 13900K	2080	4096	autorally	0.403 ± 0.035	Intel 13900K	4090	4096	autorally	0.224 ± 0.028
Intel 13900K	2080	4096	torchrl	29.1 ± 1.6	Intel 13900K	4090	4096	torchrl	28.2 ± 1.6
Intel 13900K	2080	6144	autorally	0.518 ± 0.040	Intel 13900K	4090	6144	MPPI-Generic	0.201 ± 0.028
Intel 13900K	2080	6144	MPPI-Generic	0.576 ± 0.042	Intel 13900K	4090	6144	autorally	0.233 ± 0.032
Intel 13900K	2080	6144	torchrl	29.1 ± 1.6	Intel 13900K	4090	6144	torchrl	28.4 ± 1.6
Intel 13900K	2080	8192	autorally	0.580 ± 0.044	Intel 13900K	4090	8192	MPPI-Generic	0.232 ± 0.030
Intel 13900K	2080	8192	MPPI-Generic	0.705 ± 0.043	Intel 13900K	4090	8192	autorally	0.245 ± 0.027
Intel 13900K	2080	8192	torchrl	29.4 ± 1.3	Intel 13900K	4090	8192	torchrl	28.6 ± 1.5
Intel 13900K	2080	16384	autorally	1.192 ± 0.059	Intel 13900K	4090	16384	autorally	0.338 ± 0.033
Intel 13900K	2080	16384	MPPI-Generic	1.418 ± 0.061	Intel 13900K	4090	16384	MPPI-Generic	0.389 ± 0.038
Intel 13900K	2080	16384	torchrl	32.4 ± 1.5	Intel 13900K	4090	16384	torchrl	28.6 ± 1.6

CPU	GPU	Samples	Method	Avg. Time [ms]	CPU	GPU	Samples	Method	Avg. Time [ms]
AMD 5600X	3080	128	MPPI-Generic	0.1554 ± 0.0156	Intel 13900K	3080	128	MPPI-Generic	0.1475 ± 0.0316
AMD 5600X	3080	128	autorally	0.2701 ± 0.0169	Intel 13900K	3080	128	autorally	0.245 ± 0.118
AMD 5600X		128	ros2	0.6153 ± 0.0319	Intel 13900K		128	ros2	0.3899 ± 0.0162
AMD 5600X	3080	128	torchrl	47.61 ± 1.58	Intel 13900K	3080	128	torchrl	24.77 ± 1.73
AMD 5600X	3080	256	MPPI-Generic	0.1536 ± 0.0336	Intel 13900K	3080	256	MPPI-Generic	0.1526 ± 0.0271
AMD 5600X	3080	256	autorally	0.2743 ± 0.0152	Intel 13900K	3080	256	autorally	0.2428 ± 0.0294
AMD 5600X		256	ros2	1.0804 ± 0.0427	Intel 13900K		256	ros2	0.7290 ± 0.0101
AMD 5600X	3080	256	torchrl	53.88 ± 2.02	Intel 13900K	3080	256	torchrl	28.49 ± 1.45
AMD 5600X	3080	512	MPPI-Generic	0.1528 ± 0.0115	Intel 13900K	3080	512	MPPI-Generic	0.1536 ± 0.0345
AMD 5600X	3080	512	autorally	0.2696 ± 0.0123	Intel 13900K	3080	512	autorally	0.2466 ± 0.0369
AMD 5600X		512	ros2	2.1011 ± 0.0962	Intel 13900K		512	ros2	1.4186 ± 0.0445
AMD 5600X	3080	512	torchrl	53.89 ± 2.02	Intel 13900K	3080	512	torchrl	28.58 ± 1.65
AMD 5600X	3080	1024	MPPI-Generic	0.1704 ± 0.0155	Intel 13900K	3080	1024	MPPI-Generic	0.1634 ± 0.0271
AMD 5600X	3080	1024	autorally	0.2757 ± 0.0148	Intel 13900K	3080	1024	autorally	0.2599 ± 0.0357
AMD 5600X		1024	ros2	4.752 ± 0.240	Intel 13900K		1024	ros2	3.3559 ± 0.0350
AMD 5600X	3080	1024	torchrl	53.97 ± 1.80	Intel 13900K	3080	1024	torchrl	28.68 ± 1.75
AMD 5600X	3080	2048	MPPI-Generic	0.1973 ± 0.0138	Intel 13900K	3080	2048	MPPI-Generic	0.1918 ± 0.0331
AMD 5600X	3080	2048	autorally	0.2850 ± 0.0143	Intel 13900K	3080	2048	autorally	0.2621 ± 0.0390
AMD 5600X		2048	ros2	9.500 ± 0.380	Intel 13900K		2048	ros2	6.7212 ± 0.0651
AMD 5600X	3080	2048	torchrl	54.02 ± 2.00	Intel 13900K	3080	2048	torchrl	28.68 ± 1.46
AMD 5600X	3080	4096	MPPI-Generic	0.2562 ± 0.0377	Intel 13900K	3080	4096	MPPI-Generic	0.2489 ± 0.0388
AMD 5600X	3080	4096	autorally	0.2896 ± 0.0143	Intel 13900K	3080	4096	autorally	0.2760 ± 0.0426
AMD 5600X		4096	ros2	19.583 ± 0.789	Intel 13900K		4096	ros2	13.917 ± 0.152
AMD 5600X	3080	4096	torchrl	54.15 ± 2.08	Intel 13900K	3080	4096	torchrl	28.76 ± 1.63
AMD 5600X	3080	6144	MPPI-Generic	0.3145 ± 0.0194	Intel 13900K	3080	6144	MPPI-Generic	0.3064 ± 0.0391
AMD 5600X	3080	6144	autorally	0.3362 ± 0.0143	Intel 13900K	3080	6144	autorally	0.3243 ± 0.0430
AMD 5600X		6144	ros2	29.872 ± 0.864	Intel 13900K		6144	ros2	21.739 ± 0.189
AMD 5600X	3080	6144	torchrl	54.18 ± 1.79	Intel 13900K	3080	6144	torchrl	28.83 ± 1.65
AMD 5600X	3080	8192	autorally	0.3664 ± 0.0167	Intel 13900K	3080	8192	MPPI-Generic	0.3590 ± 0.0371
AMD 5600X	3080	8192	MPPI-Generic	0.3693 ± 0.0210	Intel 13900K	3080	8192	autorally	0.3605 ± 0.0449
AMD 5600X		8192	ros2	40.64 ± 1.06	Intel 13900K		8192	torchrl	28.98 ± 1.44
AMD 5600X	3080	8192	torchrl	54.20 ± 2.09	Intel 13900K	3080	8192	ros2	29.917 ± 0.239
AMD 5600X	3080	16384	autorally	0.5121 ± 0.0183	Intel 13900K	3080	16384	autorally	0.4991 ± 0.0497
AMD 5600X	3080	16384	MPPI-Generic	0.5790 ± 0.0241	Intel 13900K	3080	16384	MPPI-Generic	0.6271 ± 0.0475
AMD 5600X		16384	torchrl	54.68 ± 1.70	Intel 13900K		16384	torchrl	29.98 ± 1.67
AMD 5600X	3080	16384	ros2	84.26 ± 1.65	Intel 13900K	3080	16384	ros2	62.264 ± 0.990
ARMv8 (v8l)	Tegra X1	128	MPPI-Generic	1.0244 ± 0.0914	ARMv8 (v8l)	Tegra X1	128	autorally	1.397 ± 0.613
ARMv8 (v8l)	Tegra X1	256	MPPI-Generic	1.3839 ± 0.0614	ARMv8 (v8l)	Tegra X1	256	autorally	1.506 ± 0.576
ARMv8 (v8l)	Tegra X1	512	autorally	1.847 ± 0.575	ARMv8 (v8l)	Tegra X1	512	MPPI-Generic	2.123 ± 0.120
ARMv8 (v8l)	Tegra X1	1024	autorally	3.245 ± 0.608	ARMv8 (v8l)	Tegra X1	1024	MPPI-Generic	4.11 ± 1.20
ARMv8 (v8l)	Tegra X1	2048	autorally	5.921 ± 0.578	ARMv8 (v8l)	Tegra X1	2048	MPPI-Generic	7.297 ± 0.399
ARMv8 (v8l)	Tegra X1	4096	autorally	11.159 ± 0.581	ARMv8 (v8l)	Tegra X1	4096	MPPI-Generic	14.124 ± 0.133
ARMv8 (v8l)	Tegra X1	6144	autorally	16.546 ± 0.605	ARMv8 (v8l)	Tegra X1	6144	MPPI-Generic	21.075 ± 0.229
ARMv8 (v8l)	Tegra X1	8192	autorally	21.767 ± 0.629	ARMv8 (v8l)	Tegra X1	8192	MPPI-Generic	28.022 ± 0.261
ARMv8 (v8l)	Tegra X1	16384	autorally	44.158 ± 0.947	ARMv8 (v8l)	Tegra X1	16384	MPPI-Generic	56.650 ± 0.351

CPU	GPU	Samples	Method	Avg. Time [ms]	CPU	GPU	Samples	Method	Avg. Time [ms]
AMD 5600X	1050 Ti	MPPI-Generic	128	0.2149±0.0478	Intel 13900K	1050 Ti	MPPI-Generic	128	0.2008 ± 0.0591
AMD 5600X	1050 Ti	autorally	128	0.4646±0.0337	Intel 13900K	1050 Ti	autorally	128	0.456 ± 0.160
AMD 5600X	1050 Ti	torchrl	128	46.65±2.25	Intel 13900K	1050 Ti	torchrl	128	25.60 ± 2.71
AMD 5600X	1050 Ti	MPPI-Generic	256	0.2265±0.0433	Intel 13900K	1050 Ti	MPPI-Generic	256	0.2257 ± 0.0578
AMD 5600X	1050 Ti	autorally	256	0.4649±0.0338	Intel 13900K	1050 Ti	autorally	256	0.4543 ± 0.0833
AMD 5600X	1050 Ti	torchrl	256	52.88±2.40	Intel 13900K	1050 Ti	torchrl	256	29.31 ± 2.44
AMD 5600X	1050 Ti	MPPI-Generic	512	0.3077±0.0525	Intel 13900K	1050 Ti	MPPI-Generic	512	0.3016 ± 0.0658
AMD 5600X	1050 Ti	autorally	512	0.4812±0.0375	Intel 13900K	1050 Ti	autorally	512	0.4688 ± 0.0802
AMD 5600X	1050 Ti	torchrl	512	52.97±2.37	Intel 13900K	1050 Ti	torchrl	512	29.91 ± 2.80
AMD 5600X	1050 Ti	MPPI-Generic	1024	0.4373±0.0548	Intel 13900K	1050 Ti	MPPI-Generic	1024	0.4294 ± 0.0753
AMD 5600X	1050 Ti	autorally	1024	0.5196±0.0397	Intel 13900K	1050 Ti	autorally	1024	0.5120 ± 0.0963
AMD 5600X	1050 Ti	torchrl	1024	53.15±2.14	Intel 13900K	1050 Ti	torchrl	1024	29.90 ± 3.00
AMD 5600X	1050 Ti	autorally	2048	0.6371±0.0433	Intel 13900K	1050 Ti	autorally	2048	0.630 ± 0.104
AMD 5600X	1050 Ti	MPPI-Generic	2048	0.8443±0.0614	Intel 13900K	1050 Ti	MPPI-Generic	2048	0.8370 ± 0.0993
AMD 5600X	1050 Ti	torchrl	2048	53.58±2.45	Intel 13900K	1050 Ti	torchrl	2048	30.39 ± 2.92
AMD 5600X	1050 Ti	autorally	4096	1.2952±0.0569	Intel 13900K	1050 Ti	autorally	4096	1.202 ± 0.132
AMD 5600X	1050 Ti	MPPI-Generic	4096	1.4836±0.0616	Intel 13900K	1050 Ti	MPPI-Generic	4096	1.468 ± 0.134
AMD 5600X	1050 Ti	torchrl	4096	55.10±2.42	Intel 13900K	1050 Ti	torchrl	4096	31.28 ± 2.71
AMD 5600X	1050 Ti	autorally	6144	1.4595±0.0618	Intel 13900K	1050 Ti	autorally	6144	1.776 ± 0.151
AMD 5600X	1050 Ti	MPPI-Generic	6144	2.1196±0.0727	Intel 13900K	1050 Ti	MPPI-Generic	6144	2.103 ± 0.155
AMD 5600X	1050 Ti	torchrl	6144	57.43±2.14	Intel 13900K	1050 Ti	torchrl	6144	34.26 ± 2.75
AMD 5600X	1050 Ti	autorally	8192	2.0762±0.0739	Intel 13900K	1050 Ti	autorally	8192	2.360 ± 0.170
AMD 5600X	1050 Ti	MPPI-Generic	8192	2.9062±0.0841	Intel 13900K	1050 Ti	MPPI-Generic	8192	2.893 ± 0.248
AMD 5600X	1050 Ti	torchrl	8192	60.50±2.45	Intel 13900K	1050 Ti	torchrl	8192	37.08 ± 2.68
AMD 5600X	1050 Ti	autorally	16384	4.108±0.113	Intel 13900K	1050 Ti	autorally	16384	4.611 ± 0.255
AMD 5600X	1050 Ti	MPPI-Generic	16384	5.665±0.126	Intel 13900K	1050 Ti	MPPI-Generic	16384	5.638 ± 0.418
AMD 5600X	1050 Ti	torchrl	16384	73.40±1.93	Intel 13900K	1050 Ti	torchrl	16384	51.97 ± 2.88
AMD 5600X	1650	MPPI-Generic	128	0.1459±0.0208	Intel 13900K	1650	MPPI-Generic	128	0.1354 ± 0.0263
AMD 5600X	1650	autorally	128	0.2555±0.0176	Intel 13900K	1650	autorally	128	0.245 ± 0.111
AMD 5600X	1650	torchrl	128	46.52±1.96	Intel 13900K	1650	torchrl	128	24.70 ± 1.77
AMD 5600X	1650	MPPI-Generic	256	0.1530±0.0188	Intel 13900K	1650	MPPI-Generic	256	0.1526 ± 0.0260
AMD 5600X	1650	autorally	256	0.2564±0.0232	Intel 13900K	1650	autorally	256	0.2385 ± 0.0284
AMD 5600X	1650	torchrl	256	52.69±2.31	Intel 13900K	1650	torchrl	256	28.54 ± 1.52
AMD 5600X	1650	MPPI-Generic	512	0.2015±0.0218	Intel 13900K	1650	MPPI-Generic	512	0.1964 ± 0.0320
AMD 5600X	1650	autorally	512	0.2649±0.0226	Intel 13900K	1650	autorally	512	0.2387 ± 0.0249
AMD 5600X	1650	torchrl	512	52.20±2.12	Intel 13900K	1650	torchrl	512	28.67 ± 1.66
AMD 5600X	1650	MPPI-Generic	1024	0.2848±0.0293	Intel 13900K	1650	MPPI-Generic	1024	0.2866 ± 0.0346
AMD 5600X	1650	autorally	1024	0.3260±0.0225	Intel 13900K	1650	autorally	1024	0.3060 ± 0.0306
AMD 5600X	1650	torchrl	1024	52.33±1.78	Intel 13900K	1650	torchrl	1024	28.78 ± 1.65
AMD 5600X	1650	autorally	2048	0.4247±0.0251	Intel 13900K	1650	autorally	2048	0.4047 ± 0.0381
AMD 5600X	1650	MPPI-Generic	2048	0.5046±0.0295	Intel 13900K	1650	MPPI-Generic	2048	0.4834 ± 0.0431
AMD 5600X	1650	torchrl	2048	52.58±2.11	Intel 13900K	1650	torchrl	2048	29.13 ± 1.46
AMD 5600X	1650	autorally	4096	0.8065±0.0447	Intel 13900K	1650	autorally	4096	0.7927 ± 0.0619
AMD 5600X	1650	MPPI-Generic	4096	1.0046±0.0448	Intel 13900K	1650	MPPI-Generic	4096	0.9680 ± 0.0636
AMD 5600X	1650	torchrl	4096	53.69±2.08	Intel 13900K	1650	torchrl	4096	30.61 ± 1.70
AMD 5600X	1650	autorally	6144	0.9841±0.0401	Intel 13900K	1650	autorally	6144	0.9418 ± 0.0623
AMD 5600X	1650	MPPI-Generic	6144	1.2299±0.0437	Intel 13900K	1650	MPPI-Generic	6144	1.1777 ± 0.0637
AMD 5600X	1650	torchrl	6144	55.53±1.80	Intel 13900K	1650	torchrl	6144	32.39 ± 1.72
AMD 5600X	1650	autorally	8192	1.3870±0.0476	Intel 13900K	1650	autorally	8192	1.3343 ± 0.0721
AMD 5600X	1650	MPPI-Generic	8192	1.7740±0.0515	Intel 13900K	1650	MPPI-Generic	8192	1.6789 ± 0.0758
AMD 5600X	1650	torchrl	8192	57.84±2.05	Intel 13900K	1650	torchrl	8192	34.52 ± 1.46
AMD 5600X	1650	autorally	16384	2.7039±0.0685	Intel 13900K	1650	autorally	16384	2.5903 ± 0.0999
AMD 5600X	1650	MPPI-Generic	16384	3.293±0.111	Intel 13900K	1650	MPPI-Generic	16384	3.128 ± 0.128
AMD 5600X	1650	torchrl	16384	68.92±1.73	Intel 13900K	1650	torchrl	16384	46.42 ± 1.73