Supplementary Material

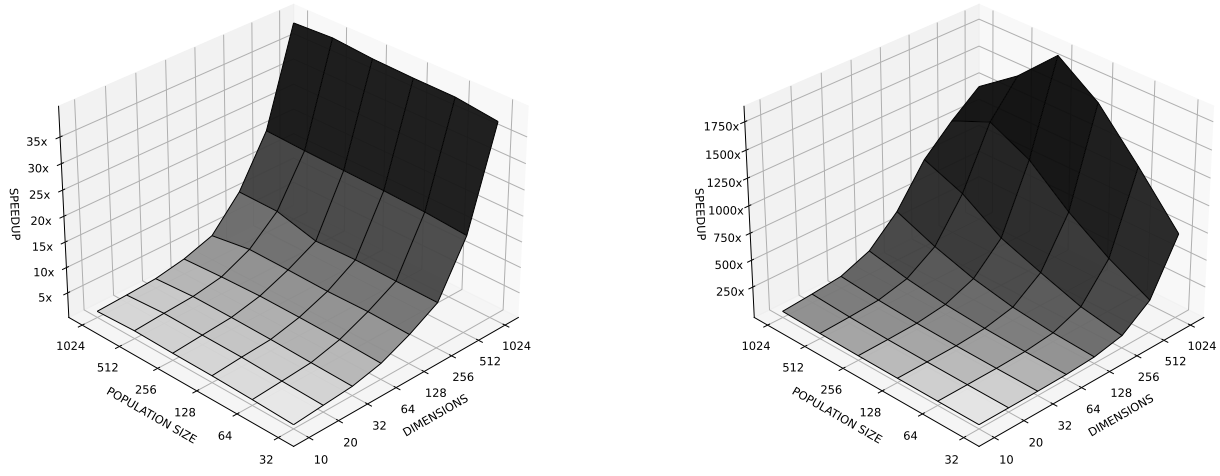
Benchmark Problems on GPU: Accelerating Experiments on Metaheuristics

The supplementary results and codes are available on GitHub.

January, 2023

TABLE I: Function 1 speed up analysis on both scenarios.

D	Population Size 32	64	128	256	512	1024
CPUCPU vs CPUGPU						
10	0.90	1.22	1.43	1.48	1.65	1.32
20	1.41	1.65	1.95	2.01	2.12	1.65
32	1.91	2.12	2.37	2.50	2.52	2.02
64	3.23	3.57	3.72	3.79	3.53	3.13
128	5.77	6.04	5.90	6.10	6.20	5.08
256	9.01	9.19	9.28	9.07	11.06	11.14
512	19.12	19.74	20.03	20.24	20.45	20.78
1024	37.92	38.90	39.02	39.24	39.87	39.46
CPUCPU vs GPUGPU						
10	0.72	1.33	2.81	5.60	11.04	20.43
20	1.47	3.04	6.24	11.66	24.20	44.43
32	2.84	5.63	11.33	21.83	42.95	75.40
64	7.71	15.56	30.67	58.08	108.31	183.14
128	23.60	46.44	88.31	164.03	278.73	427.09
256	77.68	148.57	276.37	413.59	649.28	793.18
512	266.85	463.23	709.65	1015.67	1194.89	1034.62
1024	744.55	1178.96	1585.83	1847.55	1501.13	1238.62

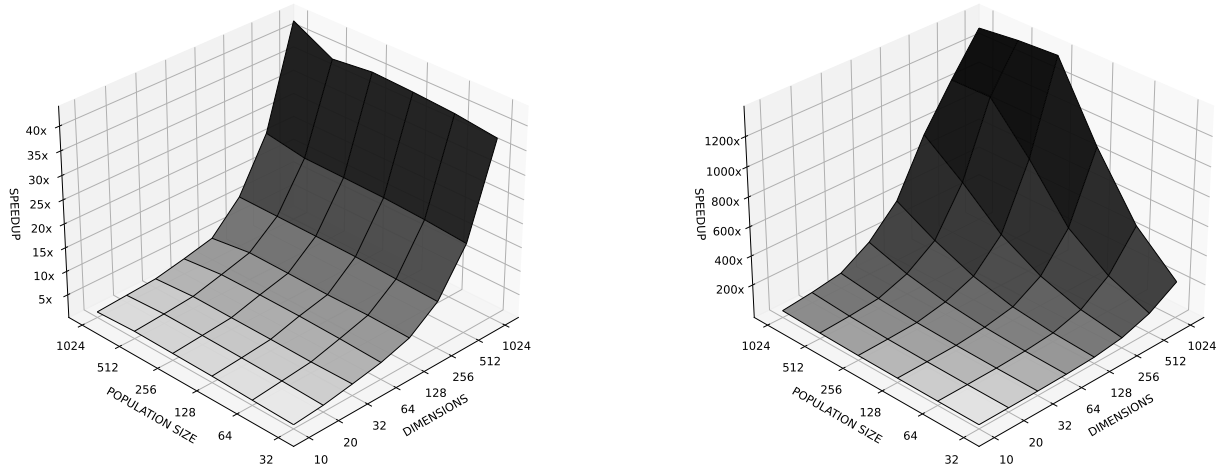


(a) CPUGPU (b) GPUGPU

Fig. 1: Function 1 - 3D plot varying population size and dimensionality.

TABLE II: Function 2 speed up analysis on both scenarios.

D	Population Size 32	64	128	256	512	1024
CPUCPU vs CPUGPU						
10	0.98	1.21	1.47	1.58	1.69	1.32
20	1.54	1.82	1.98	2.11	2.16	1.73
32	2.55	2.46	2.60	2.66	2.74	2.17
64	3.68	4.05	4.29	4.35	4.31	3.45
128	5.53	5.77	5.67	5.86	5.99	4.93
256	9.95	10.27	10.65	10.78	10.87	10.95
512	18.95	19.70	20.17	20.35	20.50	21.91
1024	37.57	38.67	39.26	39.65	38.69	43.07
CPUCPU vs GPUGPU						
10	0.74	1.49	3.12	5.91	11.54	20.06
20	1.71	3.15	6.48	12.06	24.26	44.29
32	3.36	6.01	11.82	21.66	44.04	78.48
64	7.45	15.29	31.23	61.75	116.95	197.67
128	16.10	34.08	67.95	138.41	249.77	391.10
256	42.52	90.20	180.41	330.73	559.80	765.39
512	106.18	223.53	415.65	758.51	1055.68	1058.61
1024	221.70	469.23	877.26	1368.18	1351.27	1322.62



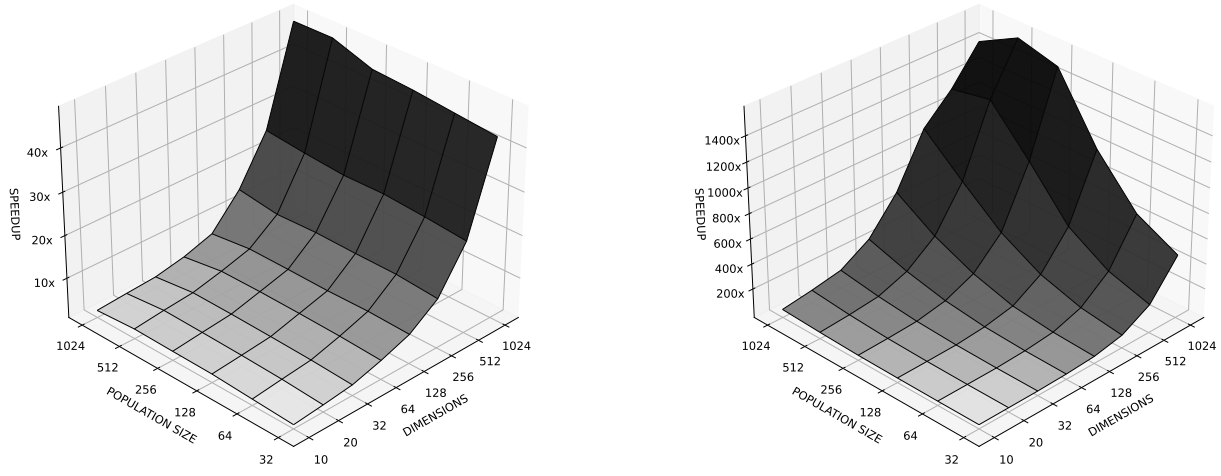
(a) CPUGPU

(b) GPUGPU

Fig. 2: Function 2 - 3D plot varying population size and dimensionality.

TABLE III: Function 3 speed up analysis on both scenarios.

D	Population Size 32	64	128	256	512	1024
CPUCPU vs CPUGPU						
10	1.61	2.12	2.65	2.77	2.94	2.35
20	2.30	2.94	3.31	3.57	3.77	2.90
32	3.14	3.69	4.04	4.32	4.47	3.38
64	5.07	5.60	5.90	6.11	6.11	4.80
128	7.48	7.85	7.75	7.95	8.07	7.03
256	12.21	13.02	13.11	13.35	13.05	14.44
512	22.13	23.04	23.77	23.66	24.46	25.50
1024	42.58	43.52	44.54	45.16	48.29	48.22
CPUCPU vs GPUGPU						
10	1.24	2.48	4.95	9.02	19.74	33.74
20	2.68	5.18	10.60	20.02	40.15	70.15
32	4.57	8.61	17.33	35.49	68.63	115.70
64	10.81	20.44	39.85	82.08	155.98	254.94
128	25.27	45.53	86.06	182.29	325.56	525.30
256	70.66	121.11	223.20	400.84	658.41	934.38
512	194.09	296.55	494.47	864.78	1228.28	1147.55
1024	471.04	642.11	1001.00	1507.19	1592.03	1429.77



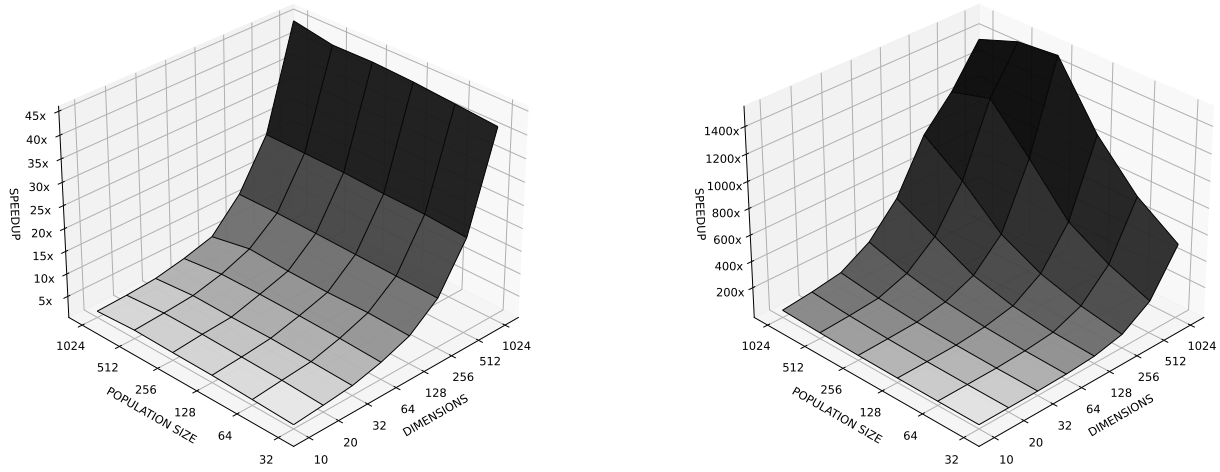
(a) CPUGPU

(b) GPUGPU

Fig. 3: Function 3 - 3D plot varying population size and dimensionality.

TABLE IV: Function 4 speed up analysis on both scenarios.

D	Population Size 32	64	128	256	512	1024
			CPUCPU vs CPUGPU			
10	1.16	1.54	1.86	1.97	2.15	1.67
20	1.74	2.18	2.39	2.59	2.59	1.96
32	2.43	2.76	3.08	3.04	3.18	2.50
64	4.03	4.45	4.70	4.81	4.75	3.78
128	6.36	6.71	6.58	6.76	7.25	5.62
256	11.27	11.52	11.79	12.03	12.22	12.17
512	21.20	21.88	22.07	22.52	22.65	22.72
1024	41.80	42.56	43.30	43.70	43.57	45.11
			CPUCPU vs GPUGPU			
10	0.94	1.69	3.92	7.32	14.83	25.54
20	2.05	4.15	8.22	15.95	30.47	52.99
32	3.88	7.16	14.74	27.41	51.57	91.25
64	9.79	18.89	37.23	68.69	132.67	219.69
128	25.59	42.38	82.48	159.62	305.68	453.00
256	73.26	128.87	218.50	370.15	631.97	843.61
512	211.98	333.93	507.01	843.36	1156.66	1072.29
1024	530.49	742.05	1061.33	1515.09	1486.45	1408.81

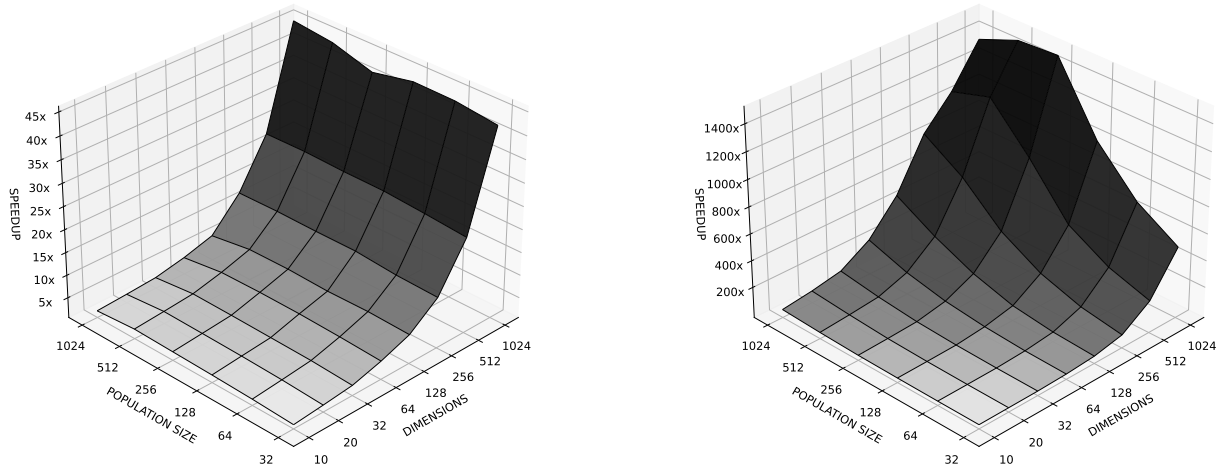


(a) CPUGPU (b) GPUGPU

Fig. 4: Function 4 - 3D plot varying population size and dimensionality.

TABLE V: Function 5 speed up analysis on both scenarios.

D	Population Size 32	64	128	256	512	1024
CPUCPU vs CPUGPU						
10	1.48	1.94	2.25	2.47	2.70	2.10
20	2.09	2.60	2.90	3.10	3.27	2.50
32	2.80	3.32	3.54	3.75	3.90	3.00
64	4.59	5.08	5.42	5.55	5.45	4.34
128	6.92	7.27	7.13	7.48	7.41	6.13
256	11.70	12.02	12.78	12.75	12.88	12.74
512	21.50	22.28	22.91	22.97	23.26	23.12
1024	42.24	43.35	43.50	41.67	44.26	45.27
CPUCPU vs GPUGPU						
10	1.17	2.33	4.52	8.40	17.76	30.87
20	2.39	4.72	9.28	18.03	37.25	60.22
32	3.81	7.65	15.54	30.71	60.52	102.31
64	10.20	18.60	38.15	72.95	138.02	233.15
128	25.43	43.61	83.28	171.19	303.51	468.42
256	68.65	119.68	218.01	385.62	649.95	839.44
512	211.48	308.62	477.84	839.71	1150.53	1059.20
1024	504.18	690.01	1003.60	1495.19	1475.22	1393.86

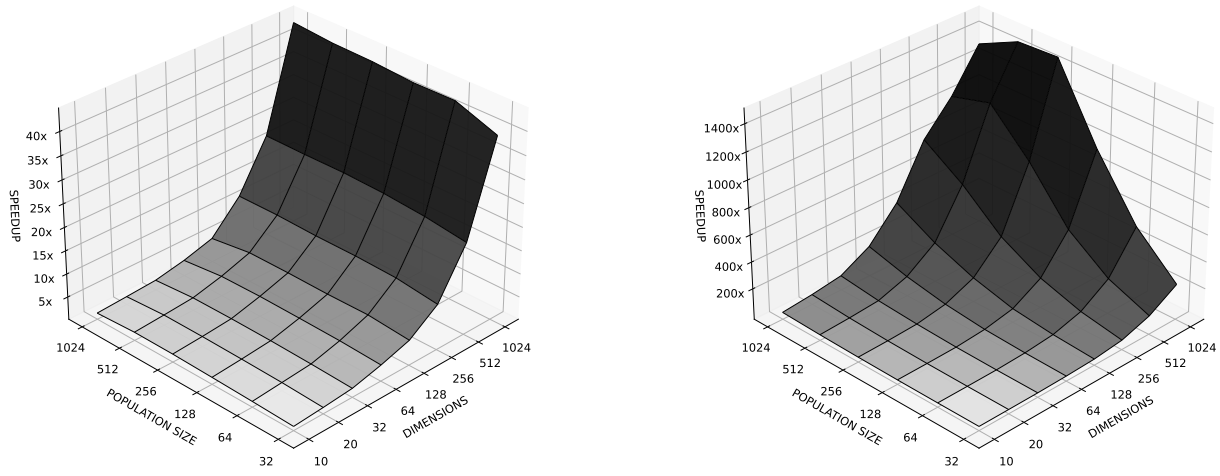


(a) CPUGPU (b) GPUGPU

Fig. 5: Function 5 - 3D plot varying population size and dimensionality.

TABLE VI: Function 6 speed up analysis on both scenarios.

D	Population Size 32	64	128	256	512	1024
CPUCPU vs CPUGPU						
10	1.01	1.35	1.62	1.86	1.90	1.50
20	1.47	1.89	2.13	2.30	2.36	1.86
32	2.05	2.44	2.73	2.88	2.88	2.28
64	3.59	4.07	4.31	4.49	4.42	3.54
128	5.52	6.33	6.28	6.45	6.48	5.38
256	9.93	11.07	11.41	11.45	11.74	11.72
512	19.90	21.13	21.86	22.16	22.09	22.14
1024	39.22	42.42	42.32	42.95	43.15	43.88
CPUCPU vs GPUGPU						
10	0.81	1.53	3.22	6.86	12.86	22.41
20	1.69	3.47	6.83	13.47	25.75	45.45
32	3.15	6.22	12.22	24.84	44.56	79.00
64	7.59	15.85	30.48	62.17	116.86	194.96
128	16.39	37.48	73.35	152.28	267.06	423.82
256	41.32	97.45	194.54	358.38	608.36	799.92
512	109.55	233.48	451.66	817.66	1111.55	1026.06
1024	234.76	516.13	947.93	1482.30	1465.92	1323.46



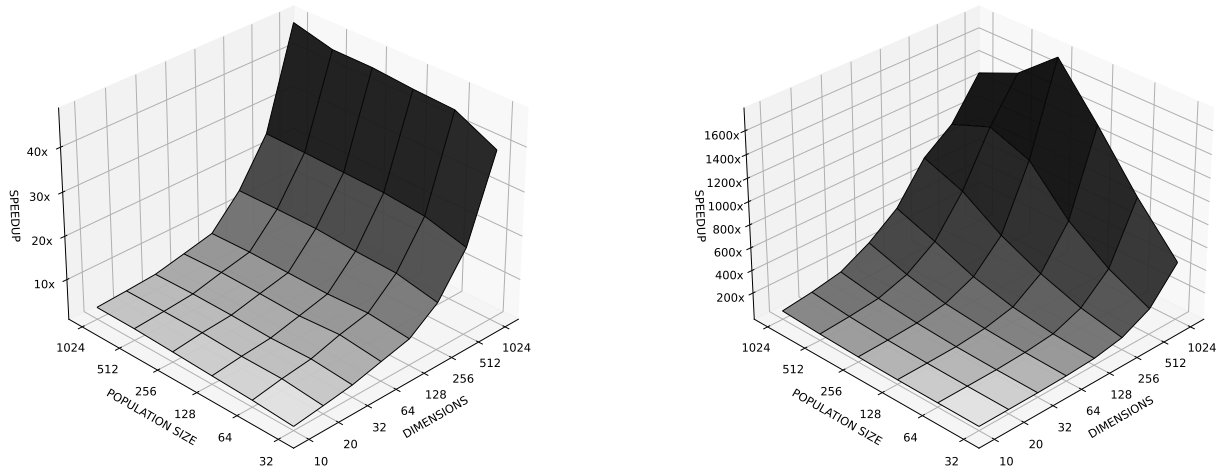
(a) CPUGPU

(b) GPUGPU

Fig. 6: Function 6 - 3D plot varying population size and dimensionality.

TABLE VII: Function 7 speed up analysis on both scenarios.

D	Population Size 32	64	128	256	512	1024
CPUCPU vs CPUGPU						
10	1.64	2.28	2.70	3.13	3.45	3.51
20	2.54	3.46	3.51	3.93	4.00	3.94
32	3.53	4.35	4.15	4.50	4.60	4.43
64	5.19	6.31	5.76	6.10	6.29	5.95
128	6.80	7.77	7.39	7.56	7.71	7.50
256	11.60	13.55	13.91	14.54	14.54	14.45
512	20.79	23.29	24.16	24.40	24.66	24.80
1024	39.42	44.10	44.51	45.29	45.36	47.62
CPUCPU vs GPUGPU						
10	1.45	2.88	5.63	11.32	22.17	40.06
20	2.91	5.95	11.66	22.16	43.65	76.65
32	4.96	9.72	19.39	39.63	73.41	130.05
64	11.70	23.36	44.94	80.19	158.42	264.04
128	26.31	51.66	102.72	190.46	328.05	451.72
256	72.55	148.57	271.77	436.18	657.29	786.13
512	193.96	366.20	616.42	979.41	1107.14	968.88
1024	475.57	876.89	1337.46	1759.29	1464.68	1312.63



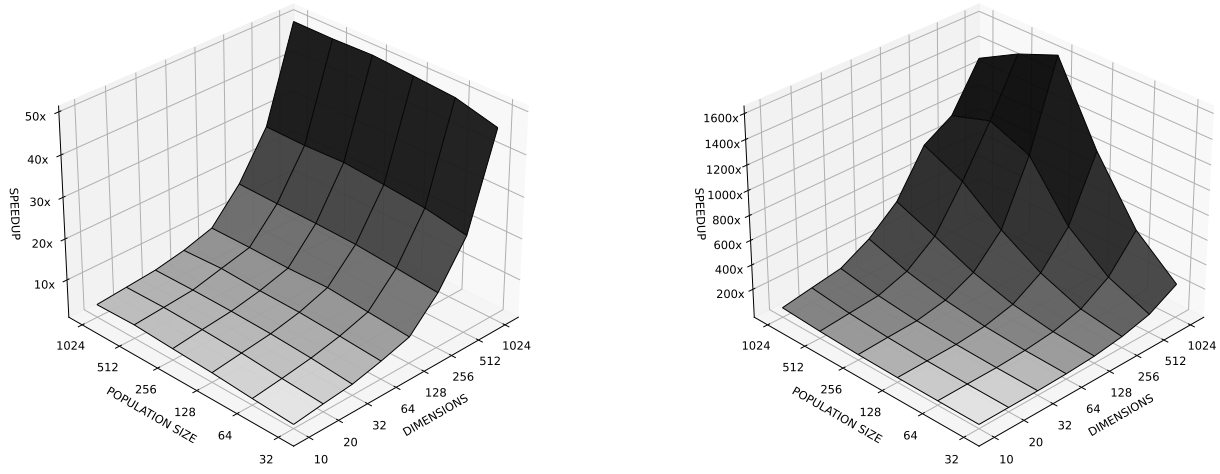
(a) CPUGPU

(b) GPUGPU

Fig. 7: Function 7 - 3D plot varying population size and dimensionality.

TABLE VIII: Function 8 speed up analysis on both scenarios.

D	Population Size 32	64	128	256	512	1024
CPUCPU vs CPUGPU						
10	1.78	2.36	3.10	3.57	4.11	3.90
20	2.67	3.27	4.05	4.47	4.70	4.60
32	3.48	4.37	5.00	5.28	5.36	5.25
64	5.17	5.89	6.47	6.68	7.12	6.64
128	7.21	8.07	8.86	8.69	8.82	8.79
256	14.20	15.07	15.89	16.17	16.26	16.45
512	24.36	26.08	27.02	27.76	27.34	27.45
1024	46.36	48.93	49.67	50.33	50.04	50.10
CPUCPU vs GPUGPU						
10	1.69	3.49	6.72	13.39	27.67	47.64
20	3.39	6.96	13.29	27.54	51.13	90.89
32	5.00	9.78	20.03	39.16	74.97	132.58
64	11.65	22.35	43.93	86.24	158.16	261.49
128	26.58	49.33	103.40	195.83	331.78	458.52
256	63.10	112.35	249.51	432.65	673.00	817.04
512	117.90	254.37	516.19	940.39	1059.65	952.82
1024	244.25	526.76	1016.08	1657.28	1496.83	1319.55



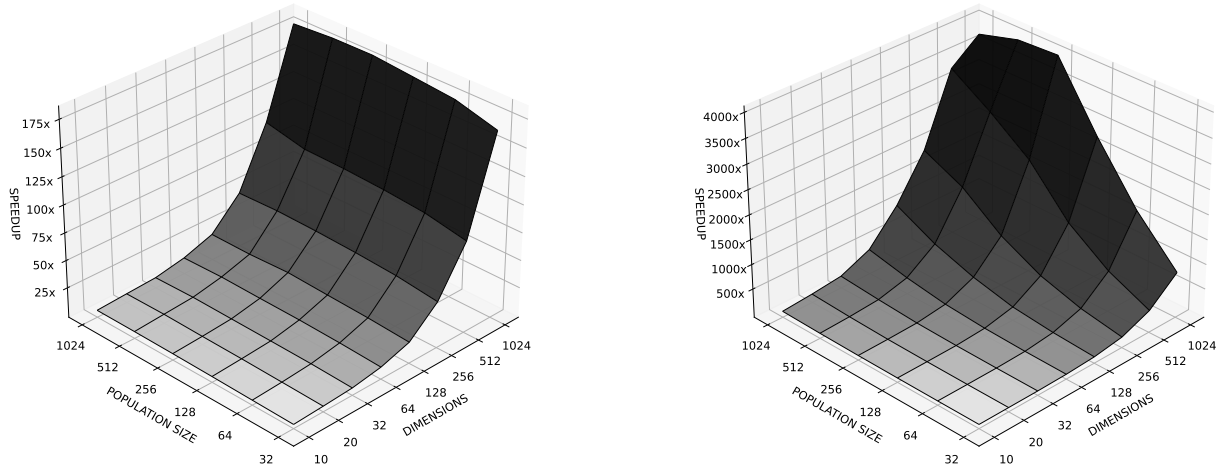
(a) CPUGPU

(b) GPUGPU

Fig. 8: Function 8 - 3D plot varying population size and dimensionality.

TABLE IX: Function 9 speed up analysis on both scenarios.

D	Population Size 32	64	128	256	512	1024
CPUCPU vs CPUGPU						
10	1.55	2.32	3.06	3.67	4.06	4.21
20	2.86	3.84	4.76	5.33	6.12	5.89
32	4.48	6.05	6.84	7.45	8.17	7.41
64	8.84	10.80	12.11	12.66	13.51	12.61
128	17.07	19.60	21.53	23.02	21.55	21.77
256	39.73	44.34	46.73	48.21	48.93	47.73
512	80.87	87.98	91.03	92.84	93.44	101.35
1024	165.53	175.66	179.20	182.59	182.18	179.69
CPUCPU vs GPUGPU						
10	1.46	2.92	5.80	11.45	22.55	40.46
20	3.30	6.43	13.21	25.48	52.16	91.80
32	5.85	12.54	24.33	47.91	99.79	164.12
64	16.24	32.79	64.51	127.17	251.11	423.83
128	48.58	103.34	192.82	384.90	659.36	1058.79
256	135.43	286.30	536.60	947.11	1548.85	1920.11
512	367.96	751.27	1329.28	2214.22	2811.67	3326.09
1024	846.07	1694.85	2790.57	4041.02	3993.69	3764.66



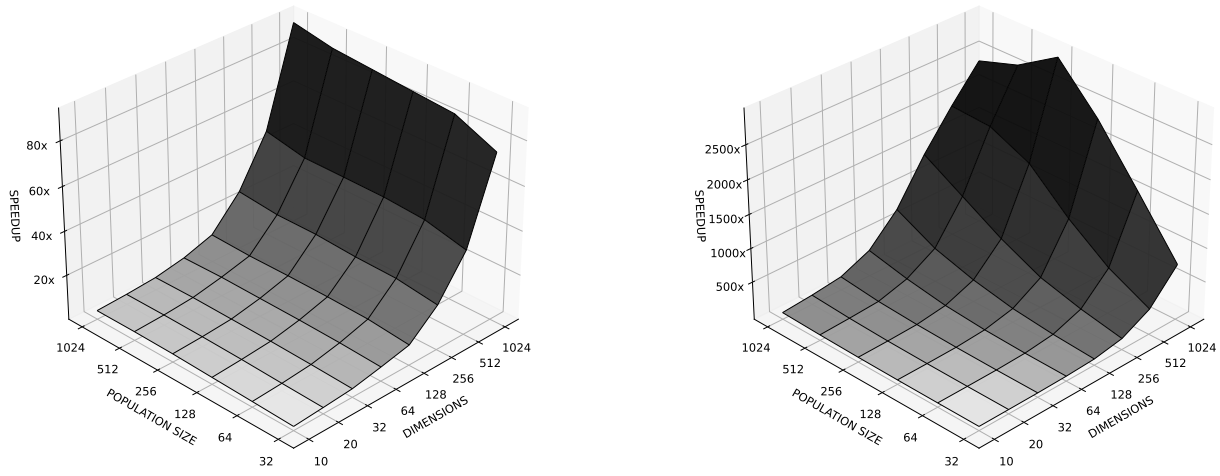
(a) CPUGPU

(b) GPUGPU

Fig. 9: Function 9 - 3D plot varying population size and dimensionality.

TABLE X: Function 10 speed up analysis on both scenarios.

D	Population Size 32	64	128	256	512	1024
CPUCPU vs CPUGPU						
10	1.56	2.24	2.84	3.47	3.72	3.72
20	2.52	3.10	3.77	4.22	4.49	4.43
32	3.59	4.38	4.99	5.37	5.70	5.51
64	6.12	7.15	7.72	8.07	8.37	8.09
128	9.02	10.97	11.51	11.73	11.75	12.46
256	20.13	22.69	23.13	24.33	24.41	26.33
512	38.15	42.69	44.04	44.30	44.52	48.41
1024	75.26	83.48	85.09	86.81	88.48	92.26
CPUCPU vs GPUGPU						
10	1.51	2.95	6.04	12.06	23.44	41.06
20	3.15	5.98	12.00	23.47	46.50	82.83
32	5.63	10.84	21.90	42.02	79.21	142.44
64	14.14	28.23	53.80	104.34	198.96	329.32
128	34.17	79.23	148.64	271.35	448.05	744.24
256	109.93	234.91	396.90	682.42	1027.79	1373.83
512	326.93	634.64	1067.92	1604.69	1873.27	1906.59
1024	789.14	1590.72	2337.95	2964.40	2587.34	2392.29

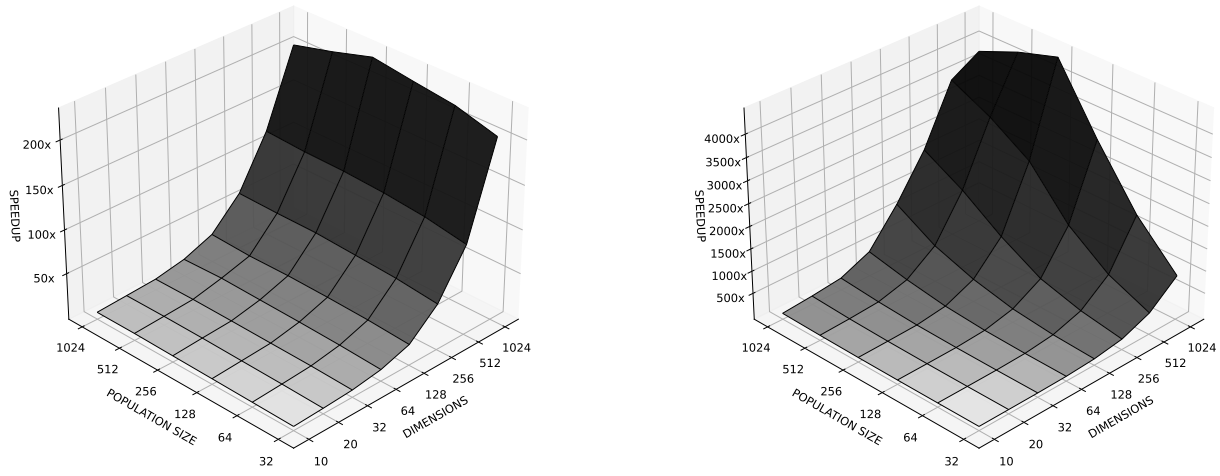


(a) CPUGPU (b) GPUGPU

Fig. 10: Function 10 - 3D plot varying population size and dimensionality.

TABLE XI: Function 11 speed up analysis on both scenarios.

D	Population Size 32	64	128	256	512	1024
CPUCPU vs CPUGPU						
10	1.73	2.63	3.45	4.28	5.06	5.11
20	3.28	4.71	5.78	6.82	7.40	7.44
32	5.35	7.16	8.12	9.15	9.90	9.77
64	10.29	13.08	14.89	16.30	17.71	16.49
128	20.90	24.43	26.33	27.51	27.30	29.72
256	49.51	54.90	57.92	60.72	61.02	62.07
512	100.02	108.49	113.38	116.11	116.99	119.68
1024	203.88	217.03	223.21	229.95	216.40	204.62
CPUCPU vs GPUGPU						
10	1.68	3.13	6.38	12.71	25.13	44.47
20	3.72	7.27	14.89	29.94	56.74	103.25
32	6.68	13.62	26.94	51.85	104.71	183.58
64	17.00	34.96	68.79	141.49	279.26	465.42
128	53.65	109.37	215.81	422.50	734.87	1244.16
256	148.75	309.18	572.90	1074.02	1687.72	2178.16
512	395.72	795.80	1460.94	2469.61	3032.91	3461.70
1024	903.91	1814.90	3064.15	4464.54	4189.11	3824.29

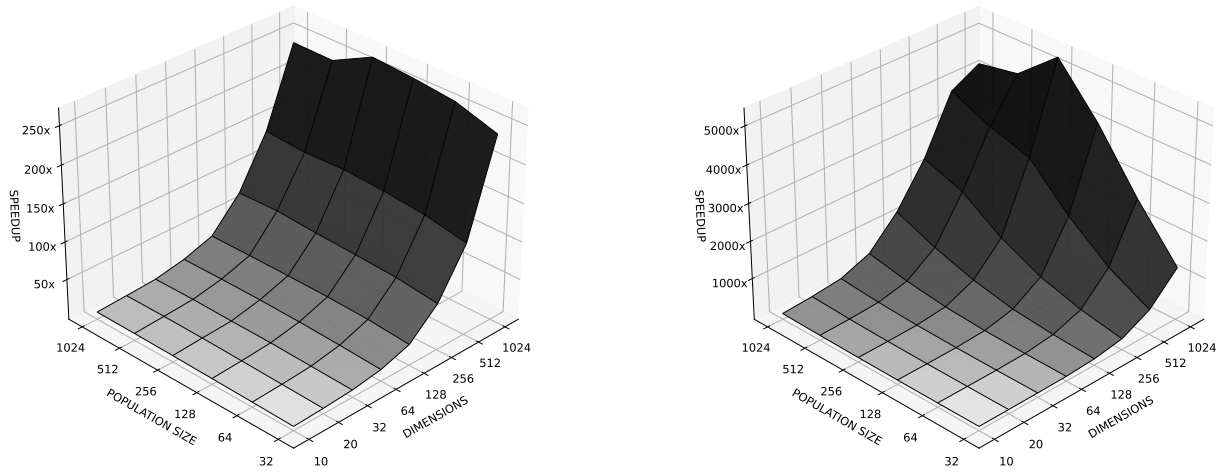


(a) CPUGPU (b) GPUGPU

Fig. 11: Function 11 - 3D plot varying population size and dimensionality.

TABLE XII: Function 12 speed up analysis on both scenarios.

D	Population Size 32	64	128	256	512	1024
CPUCPU vs CPUGPU						
10	1.85	3.07	4.02	5.04	5.72	6.08
20	3.55	5.01	6.50	7.85	8.43	8.48
32	6.00	7.75	9.68	10.23	11.37	11.25
64	11.77	14.93	17.30	18.81	19.27	18.92
128	24.21	28.89	31.04	32.02	32.29	32.00
256	57.83	64.76	67.72	70.27	73.85	72.37
512	117.54	128.41	133.74	136.74	134.84	138.58
1024	239.63	256.60	262.85	266.71	239.57	240.30
CPUCPU vs GPUGPU						
10	1.74	3.62	6.99	13.83	26.93	47.38
20	3.92	7.62	15.38	31.29	60.36	108.67
32	7.54	14.54	29.31	58.28	112.83	213.28
64	18.87	38.88	76.59	150.13	294.54	511.68
128	64.88	137.80	253.05	485.01	831.10	1275.69
256	190.34	414.04	738.86	1255.15	1982.44	2363.04
512	578.69	1155.49	2010.79	3052.77	3379.70	3846.32
1024	1326.82	2661.17	4169.64	5365.68	4451.50	4248.53



(a) CPUGPU (b) GPUGPU

Fig. 12: Function 12 - 3D plot varying population size and dimensionality.

TABLE XIII: Optimization effectiveness comparison between CPUCPU, CPUGPU, and GPUGPU versions considering 10 dimensions.

		CPUCPU	CPUGPU	GPUGPU
F1	Best	$0.00E+00$	$0.00E+00$	$0.00E+00$
	Median	$0.00E+00$	$0.00E+00$	$0.00E+00$
	Worst	$0.00E+00$	$0.00E+00$	$0.00E+00$
	Mean	$0.00E+00$	$0.00E+00$	$0.00E+00$
	Std	$0.00E+00$	$0.00E+00$	$0.00E+00$
F2	Best	$0.00E+00$	$0.00E+00$	$0.00E+00$
	Median	$1.05E-09$	$0.00E+00$	$0.00E+00$
	Worst	$9.25E-02$	$3.44E-05$	$9.91E-08$
	Mean	$2.41E-03$	$3.45E-07$	$9.95E-10$
	Std	$1.33E-02$	$3.43E-06$	$9.86E-09$
F3	Best	$1.70E-09$	$1.00E-09$	$8.20E-09$
	Median	$7.97E-08$	$6.94E-08$	$8.48E-08$
	Worst	$5.42E-07$	$3.22E-07$	$4.34E-07$
	Mean	$1.03E-07$	$8.41E-08$	$1.05E-07$
	Std	$9.30E-08$	$6.58E-08$	$8.56E-08$
F4	Best	$1.29E+01$	$1.36E+01$	$1.45E+01$
	Median	$2.47E+01$	$2.58E+01$	$2.66E+01$
	Worst	$3.43E+01$	$3.28E+01$	$3.41E+01$
	Mean	$2.45E+01$	$2.53E+01$	$2.65E+01$
	Std	$4.12E+00$	$3.83E+00$	$3.68E+00$
F5	Best	$0.00E+00$	$0.00E+00$	$0.00E+00$
	Median	$0.00E+00$	$0.00E+00$	$0.00E+00$
	Worst	$0.00E+00$	$0.00E+00$	$0.00E+00$
	Mean	$0.00E+00$	$0.00E+00$	$0.00E+00$
	Std	$0.00E+00$	$0.00E+00$	$0.00E+00$
F6	Best	$2.86E-02$	$3.58E-01$	$4.14E-01$
	Median	$2.52E-01$	$5.00E-01$	$5.00E-01$
	Worst	$1.45E+00$	$5.00E-01$	$1.49E+00$
	Mean	$2.91E-01$	$4.97E-01$	$5.08E-01$
	Std	$1.80E-01$	$1.81E-02$	$9.98E-02$
F7	Best	$8.45E+00$	$1.04E+01$	$9.65E+00$
	Median	$2.50E+01$	$2.48E+01$	$2.52E+01$
	Worst	$3.23E+01$	$3.14E+01$	$3.13E+01$
	Mean	$2.44E+01$	$2.38E+01$	$2.41E+01$
	Std	$3.90E+00$	$4.16E+00$	$4.45E+00$
F8	Best	$1.59E+00$	$1.43E+00$	$1.53E+00$
	Median	$3.32E+00$	$3.28E+00$	$3.17E+00$
	Worst	$8.21E+00$	$7.18E+00$	$6.19E+00$
	Mean	$3.56E+00$	$3.52E+00$	$3.31E+00$
	Std	$1.30E+00$	$1.28E+00$	$9.94E-01$
F9	Best	$1.55E+02$	$1.55E+02$	$1.55E+02$
	Median	$1.55E+02$	$1.55E+02$	$1.55E+02$
	Worst	$1.55E+02$	$1.55E+02$	$1.55E+02$
	Mean	$1.55E+02$	$1.55E+02$	$1.55E+02$
	Std	$2.84E-14$	$2.84E-14$	$2.84E-14$
F10	Best	$1.00E+02$	$1.00E+02$	$1.00E+02$
	Median	$1.00E+02$	$1.00E+02$	$1.00E+02$
	Worst	$2.29E+02$	$2.28E+02$	$2.24E+02$
	Mean	$1.23E+02$	$1.17E+02$	$1.02E+02$
	Std	$4.70E+01$	$4.09E+01$	$1.23E+01$
F11	Best	$0.00E+00$	$0.00E+00$	$0.00E+00$
	Median	$0.00E+00$	$0.00E+00$	$0.00E+00$
	Worst	$3.00E+02$	$3.00E+02$	$0.00E+00$
	Mean	$6.00E+00$	$3.00E+00$	$0.00E+00$
	Std	$4.20E+01$	$2.98E+01$	$0.00E+00$
F12	Best	$2.10E+02$	$2.10E+02$	$2.10E+02$
	Median	$2.11E+02$	$2.11E+02$	$2.12E+02$
	Worst	$2.19E+02$	$2.15E+02$	$2.15E+02$
	Mean	$2.12E+02$	$2.12E+02$	$2.12E+02$
	Std	$1.19E+00$	$6.00E-01$	$6.66E-01$

TABLE XIV: Optimization effectiveness comparison between CPUCPU, CPUGPU, and GPUGPU versions considering 20 dimensions.

		CPUCPU	CPUGPU	GPUGPU
F1	Best	$7.88E-03$	$4.22E-03$	$4.89E-02$
	Median	$6.66E-02$	$6.04E-02$	$4.60E-01$
	Worst	$6.35E-01$	$3.89E-01$	$4.50E+00$
	Mean	$1.10E-01$	$8.08E-02$	$7.61E-01$
	Std	$1.20E-01$	$6.59E-02$	$8.38E-01$
F2	Best	$2.90E-03$	$8.46E-04$	$2.69E-04$
	Median	$4.32E-01$	$1.72E-01$	$1.41E-01$
	Worst	$1.68E+00$	$4.17E+00$	$4.04E+00$
	Mean	$5.40E-01$	$4.43E-01$	$3.15E-01$
	Std	$4.01E-01$	$9.04E-01$	$6.87E-01$
F3	Best	$9.98E-04$	$8.05E-04$	$1.35E-03$
	Median	$2.94E-03$	$2.77E-03$	$3.71E-03$
	Worst	$6.43E-03$	$8.97E-03$	$1.11E-02$
	Mean	$3.06E-03$	$3.15E-03$	$4.21E-03$
	Std	$1.19E-03$	$1.51E-03$	$1.80E-03$
F4	Best	$7.55E+01$	$8.54E+01$	$7.82E+01$
	Median	$1.04E+02$	$1.04E+02$	$1.05E+02$
	Worst	$1.19E+02$	$1.18E+02$	$1.17E+02$
	Mean	$1.04E+02$	$1.03E+02$	$1.02E+02$
	Std	$7.68E+00$	$6.35E+00$	$9.56E+00$
F5	Best	$0.00E+00$	$0.00E+00$	$0.00E+00$
	Median	$0.00E+00$	$0.00E+00$	$2.00E-10$
	Worst	$5.00E-10$	$7.00E-10$	$4.40E-09$
	Mean	$6.80E-11$	$7.30E-11$	$5.07E-10$
	Std	$1.05E-10$	$1.08E-10$	$7.54E-10$
F6	Best	$7.49E+01$	$8.08E+01$	$8.67E+01$
	Median	$1.86E+02$	$1.81E+02$	$1.89E+02$
	Worst	$1.11E+03$	$7.96E+02$	$7.49E+02$
	Mean	$2.10E+02$	$2.07E+02$	$2.29E+02$
	Std	$1.25E+02$	$1.08E+02$	$1.31E+02$
F7	Best	$5.56E+01$	$5.54E+01$	$5.89E+01$
	Median	$7.58E+01$	$7.67E+01$	$1.15E+02$
	Worst	$1.01E+02$	$1.01E+02$	$1.61E+02$
	Mean	$7.61E+01$	$7.68E+01$	$1.14E+02$
	Std	$1.07E+01$	$1.05E+01$	$2.07E+01$
F8	Best	$2.84E+01$	$2.98E+01$	$3.02E+01$
	Median	$3.38E+01$	$3.37E+01$	$3.55E+01$
	Worst	$4.00E+01$	$4.03E+01$	$5.08E+01$
	Mean	$3.37E+01$	$3.39E+01$	$3.66E+01$
	Std	$2.34E+00$	$2.25E+00$	$4.56E+00$
F9	Best	$2.69E+02$	$2.69E+02$	$2.69E+02$
	Median	$2.69E+02$	$2.69E+02$	$2.69E+02$
	Worst	$2.69E+02$	$2.69E+02$	$2.69E+02$
	Mean	$2.69E+02$	$2.69E+02$	$2.69E+02$
	Std	$1.56E-09$	$1.65E-09$	$2.06E-06$
F10	Best	$1.00E+02$	$1.00E+02$	$1.00E+02$
	Median	$1.00E+02$	$1.00E+02$	$1.02E+02$
	Worst	$3.01E+02$	$3.51E+03$	$1.05E+02$
	Mean	$1.11E+02$	$1.74E+02$	$1.02E+02$
	Std	$4.19E+01$	$4.57E+02$	$1.24E+00$
F11	Best	$2.42E-06$	$1.13E-05$	$1.02E-04$
	Median	$4.00E+02$	$4.00E+02$	$4.00E+02$
	Worst	$4.00E+02$	$4.00E+02$	$4.00E+02$
	Mean	$3.45E+02$	$3.70E+02$	$3.53E+02$
	Std	$7.79E+01$	$5.74E+01$	$6.08E+01$
F12	Best	$2.54E+02$	$2.54E+02$	$2.61E+02$
	Median	$2.65E+02$	$2.63E+02$	$2.66E+02$
	Worst	$2.70E+02$	$2.69E+02$	$2.76E+02$
	Mean	$2.64E+02$	$2.63E+02$	$2.67E+02$
	Std	$3.95E+00$	$3.94E+00$	$1.86E+00$

TABLE XV: Speed up comparison CPUCPU vs CPUGPU.

Function	D	Population Size 32	64	128	256	512
F1	10	1.0049	1.2837	1.4718	1.6012	1.6474
	20	1.4853	1.7307	1.9762	2.0315	2.0304
	32	2.0395	2.2502	2.3326	2.5080	2.5755
	64	3.2330	3.5422	3.7136	3.8182	3.9976
	128	5.7266	6.0660	6.4416	6.4273	6.3568
F2	10	0.8373	1.0314	1.2026	1.3115	1.3793
	20	1.3033	1.4847	1.5944	1.7117	1.7493
	32	2.0500	1.9947	2.0921	2.1458	2.2104
	64	2.9852	3.3136	3.4682	3.4772	3.6954
	128	5.4404	5.7335	6.0502	6.1434	6.0444
F3	10	1.2225	1.6756	2.0637	2.2283	2.3472
	20	1.9609	2.4207	2.7457	2.8628	3.0911
	32	2.6676	3.0132	3.2365	3.4390	3.6114
	64	4.0381	4.5831	4.7091	4.9196	5.1832
	128	6.7819	6.9919	7.6276	7.7190	7.5360
F4	10	0.9717	1.2850	1.5261	1.6480	1.7629
	20	1.4825	1.7769	1.9537	2.1335	2.1337
	32	1.9705	2.2778	2.4868	2.5694	2.5602
	64	3.3130	3.6482	3.8058	3.9164	4.0340
	128	5.6536	6.0489	6.5527	6.5947	6.4796
F5	10	1.1553	1.5670	1.7930	2.0046	2.2208
	20	1.7801	2.1877	2.3256	2.4822	2.6574
	32	2.3607	2.6986	2.9528	3.0507	3.1819
	64	3.7395	4.0576	4.3519	4.4361	4.5712
	128	6.4704	6.5650	7.1145	7.2040	7.0967
F6	10	0.9031	1.1252	1.3667	1.5235	1.5694
	20	1.3171	1.6039	1.7545	1.8844	1.9392
	32	1.7552	2.0141	2.2456	2.3070	2.3368
	64	3.0636	3.2319	3.4914	3.6409	3.7235
	128	5.4234	5.8121	6.2301	6.1551	6.2124
F7	10	1.4787	2.0285	2.6254	3.0871	3.4314
	20	2.3131	2.9611	3.5743	3.8731	4.0276
	32	3.0839	3.6923	4.1621	4.5769	4.7685
	64	4.3749	5.2805	5.7099	6.1120	6.2969
	128	7.3372	7.8859	8.8903	8.5209	8.8707
F8	10	1.8340	2.5553	3.0993	3.5958	4.2312
	20	2.8205	3.4441	4.0913	4.6320	4.7540
	32	3.1323	4.1055	4.9081	5.2222	5.4410
	64	5.0202	5.9123	6.4355	6.8790	7.1495
	128	8.1259	8.7517	9.6532	9.3450	9.5346
F9	10	1.5112	2.3122	3.1543	3.7270	4.1684
	20	2.7852	3.7572	4.8360	5.4498	6.0401
	32	4.4052	5.8131	6.6659	7.3347	8.1319
	64	8.5324	10.6828	12.1079	12.9624	13.6532
	128	18.0569	20.4904	23.3714	23.3897	23.2303
F10	10	1.5355	2.1704	2.9089	3.3813	3.6447
	20	2.5316	3.1328	3.7212	4.3298	4.4520
	32	3.4970	4.3546	5.0299	5.2939	5.5640
	64	5.9962	7.0500	7.5213	8.0897	8.4458
	128	11.4029	12.2270	13.3238	13.1340	13.3255
F11	10	1.7449	2.6190	3.4807	4.3405	4.9488
	20	3.1975	4.6171	5.8978	6.8454	7.4470
	32	5.1223	6.8942	8.3422	9.2618	10.1108
	64	10.1636	12.6482	14.2953	16.5490	17.8434
	128	22.6399	25.7459	28.3133	29.1850	29.9883
F12	10	1.8016	2.9833	3.9800	5.0392	5.7128
	20	3.4039	4.9847	6.4152	7.6751	8.2870
	32	5.6491	7.8320	9.4589	10.6671	11.5056
	64	11.2211	14.2702	16.8829	18.5461	19.9087
	128	25.5787	28.9258	36.0553	34.2609	34.1442

TABLE XVI: Speed up comparison CPUCPU vs GPUGPU.

Function	D	Population Size 32	64	128	256	512
F1	10	0.9163	1.8426	3.6869	7.1263	14.0769
	20	1.9989	3.4308	8.1435	15.0599	30.4093
	32	3.7084	6.9932	14.5510	27.8354	54.4344
	64	9.6171	18.5063	37.9101	72.4286	137.9275
	128	30.8195	60.6136	113.5091	208.0021	361.7537
F2	10	0.7396	1.4884	3.1247	5.9120	11.5400
	20	1.7131	3.1549	6.4804	12.0597	24.2618
	32	3.3585	6.0142	11.8176	21.6571	44.0429
	64	7.4505	15.2884	31.2349	61.7451	116.9461
	128	19.9830	43.0689	84.0308	172.7603	311.0994
F3	10	1.2433	2.4777	4.9514	9.0199	19.7407
	20	2.6848	5.1765	10.5971	20.0247	40.1504
	32	4.5717	8.6077	17.3278	35.4852	68.6349
	64	10.8115	20.4377	39.8478	82.0761	155.9810
	128	29.1425	51.5750	97.0307	211.4152	373.8929
F4	10	0.9366	1.6908	3.9240	7.3231	14.8314
	20	2.0534	4.1463	8.2238	15.9472	30.4653
	32	3.8781	7.1619	14.7374	27.4078	51.5722
	64	9.7911	18.8901	37.2305	68.6891	132.6653
	128	29.1051	47.6939	94.4639	183.9291	335.5619
F5	10	1.1738	2.3297	4.5217	8.4039	17.7608
	20	2.3884	4.7201	9.2763	18.0304	37.2534
	32	3.8075	7.6486	15.5371	30.7143	60.5234
	64	10.1980	18.6006	38.1536	72.9534	138.0152
	128	29.8537	49.8644	94.7161	196.5256	353.8574
F6	10	0.8340	1.5455	3.2325	6.8496	12.8653
	20	1.7018	3.4819	6.9004	13.5342	25.7798
	32	3.1453	6.2765	12.2384	24.8786	44.2255
	64	7.5944	15.8500	30.7169	62.3856	118.0957
	128	19.7086	42.4900	83.3192	170.4552	310.9984
F7	10	1.4515	2.9009	5.6569	11.3625	22.1324
	20	2.9289	6.0125	11.8377	22.3072	43.6807
	32	5.0710	9.7345	19.4123	39.5944	73.7533
	64	11.7010	23.3914	45.5534	80.6468	161.2269
	128	31.6506	62.1527	119.4122	219.7116	380.9589
F8	10	1.7134	3.4977	6.7266	13.4286	27.1295
	20	3.4428	7.0044	13.3948	27.7906	51.8206
	32	5.0721	9.8665	20.2640	39.3942	75.6064
	64	11.7293	22.3757	43.6817	86.6957	157.9644
	128	28.5565	52.5364	109.0003	209.6885	354.6959
F9	10	1.4728	2.9447	5.8473	11.4457	22.6880
	20	3.3314	6.4534	13.2666	25.5021	52.0238
	32	5.6631	12.6452	24.3746	48.1121	100.8470
	64	16.3139	32.8412	64.9517	127.8065	253.6541
	128	51.9664	109.0055	205.9043	387.3212	717.9901
F10	10	1.5088	2.9606	6.0977	12.0414	23.3645
	20	3.2536	5.9990	12.0160	23.8637	46.3336
	32	5.6293	10.8909	22.1032	42.1042	76.4760
	64	13.5647	27.2122	53.6244	105.1803	200.4914
	128	41.9903	88.2331	169.5954	309.7885	514.6195
F11	10	1.7020	3.1511	6.4259	12.7542	25.1050
	20	3.7228	7.3051	14.9011	29.9033	56.9938
	32	6.7845	13.7383	27.2969	52.4329	105.8745
	64	17.1478	35.1702	68.9905	142.2127	281.9755
	128	57.6601	116.3493	230.8193	452.9035	797.4529
F12	10	1.7601	3.6309	7.0361	13.7715	26.9125
	20	3.9374	7.6993	15.5778	31.3285	60.3408
	32	7.5913	14.2104	29.7332	58.8859	113.3319
	64	18.7945	39.3297	76.7870	151.6194	297.2210
	128	67.5341	142.4462	295.7921	521.7928	876.9030

TABLE XVII: Speed up comparison CPUGPU vs GPUGPU.

Function	D	Population Size 32	64	128	256	512
F1	10	0.9117	1.4355	2.5051	4.4506	8.5447
	20	1.3457	1.9823	4.1208	7.4130	14.9771
	32	1.8182	3.1078	6.2382	11.0989	21.1357
	64	2.9747	5.2245	10.2085	18.9691	34.5028
	128	5.3818	9.9924	17.6211	32.3623	56.9079
F2	10	0.8832	1.4431	2.5983	4.5078	8.3668
	20	1.3144	2.1250	4.0645	7.0454	13.8692
	32	1.6383	3.0150	5.6488	10.0927	19.9253
	64	2.4958	4.6139	9.0062	17.7569	31.6461
	128	3.6731	7.5117	13.8888	28.1213	51.4689
F3	10	1.0170	1.4788	2.3993	4.0480	8.4104
	20	1.3691	2.1384	3.8595	6.9949	12.9891
	32	1.7138	2.8566	5.3538	10.3184	19.0052
	64	2.6774	4.4594	8.4618	16.6835	30.0934
	128	4.2971	7.3764	12.7211	27.3890	49.6144
F4	10	0.9639	1.3158	2.5713	4.4437	8.4132
	20	1.3851	2.3334	4.2095	7.4746	14.2784
	32	1.9681	3.1442	5.9262	10.6671	20.1442
	64	2.9554	5.1779	9.7825	17.5389	32.8871
	128	5.1481	7.8847	14.4159	27.8904	51.7871
F5	10	1.0160	1.4867	2.5219	4.1922	7.9976
	20	1.3417	2.1576	3.9887	7.2640	14.0188
	32	1.6129	2.8342	5.2619	10.0679	19.0211
	64	2.7271	4.5841	8.7672	16.4452	30.1921
	128	4.6139	7.5955	13.3132	27.2800	49.8619
F6	10	0.9235	1.3736	2.3652	4.4959	8.1978
	20	1.2921	2.1709	3.9331	7.1822	13.2941
	32	1.7920	3.1163	5.4500	10.7842	18.9260
	64	2.4789	4.9042	8.7978	17.1346	31.7161
	128	3.6340	7.3106	13.3736	27.6931	50.0609
F7	10	0.9816	1.4301	2.1547	3.6807	6.4500
	20	1.2662	2.0305	3.3119	5.7595	10.8453
	32	1.6444	2.6364	4.6640	8.6509	15.4666
	64	2.6746	4.4298	7.9780	13.1947	25.6041
	128	4.3137	7.8815	13.4318	25.7849	42.9458
F8	10	0.9342	1.3688	2.1704	3.7346	6.4117
	20	1.2207	2.0337	3.2740	5.9997	10.9004
	32	1.6193	2.4032	4.1287	7.5437	13.8956
	64	2.3364	3.7846	6.7876	12.6030	22.0945
	128	3.5143	6.0030	11.2917	22.4387	37.2010
F9	10	0.9746	1.2735	1.8538	3.0710	5.4429
	20	1.1961	1.7176	2.7433	4.6795	8.6131
	32	1.2855	2.1753	3.6566	6.5595	12.4014
	64	1.9120	3.0742	5.3644	9.8598	18.5783
	128	2.8779	5.3198	8.8101	16.5595	30.9075
F10	10	0.9826	1.3640	2.0963	3.5611	6.4106
	20	1.2852	1.9149	3.2291	5.5115	10.4074
	32	1.6098	2.5010	4.3943	7.9533	13.7447
	64	2.2622	3.8599	7.1296	13.0017	23.7386
	128	3.6824	7.2162	12.7287	23.5868	38.6192
F11	10	0.9754	1.2032	1.8462	2.9384	5.0729
	20	1.1643	1.5822	2.5266	4.3683	7.6532
	32	1.3245	1.9927	3.2721	5.6612	10.4714
	64	1.6872	2.7807	4.8261	8.5934	15.8028
	128	2.5468	4.5191	8.1523	15.5184	26.5921
F12	10	0.9770	1.2171	1.7679	2.7328	4.7109
	20	1.1567	1.5446	2.4283	4.0819	7.2814
	32	1.3438	1.8144	3.1434	5.5203	9.8502
	64	1.6749	2.7561	4.5482	8.1753	14.9292
	128	2.6403	4.9245	8.2038	15.2300	25.6823