

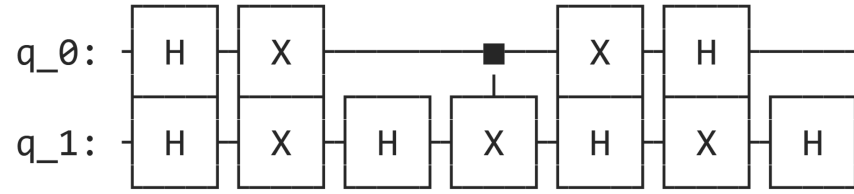
Quantum Program Improvement with Multi-Objective Genetic Programming Support Material

References

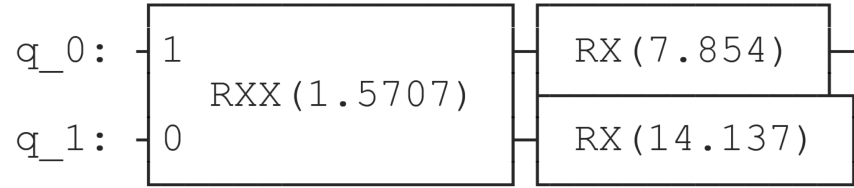
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Table 1: Number of quantum program use cases per library and number of qubits (specific + arbitrary input state)

Library	2 qubits	3 qubits	4 qubits	5 qubits	Total
[Zhao et al., 2021]	2 + 1	1 + 1	1 + 1	1 + 1	5 + 4
[Quetschlich et al., 2022]	2 + 2	3 + 2	3 + 2	3 + 2	11 + 8
[Li et al., 2023]	0 + 2	2 + 3	3 + 2	1 + 1	6 + 8
[Tomesch et al., 2022]	0 + 1	0 + 1	0 + 1	0 + 1	0 + 4
[Lubinski et al., 2021]	0 + 0	0 + 1	0 + 0	0 + 0	0 + 1
Sum	4 + 6	6 + 8	7 + 6	5 + 5	22 + 25

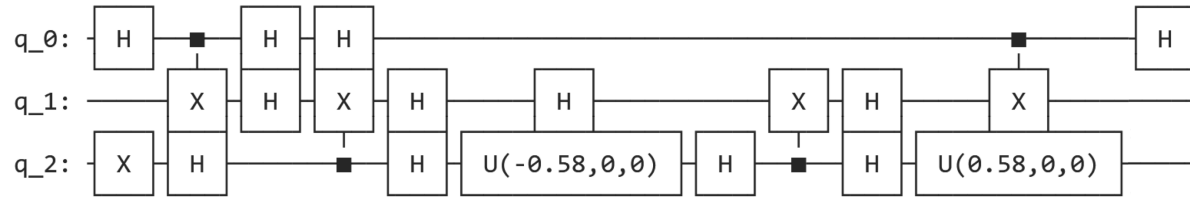


(a) Reference — 11 Gates

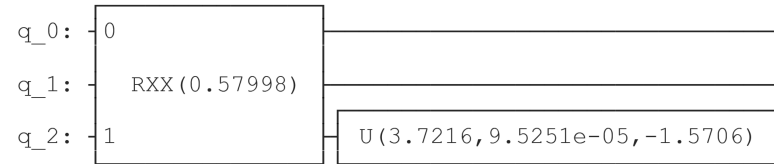


(b) Hybrid (Perfect Accuracy; Seed 6) — 3 Gates

Figure 1: Optimization Example on Problem AA2

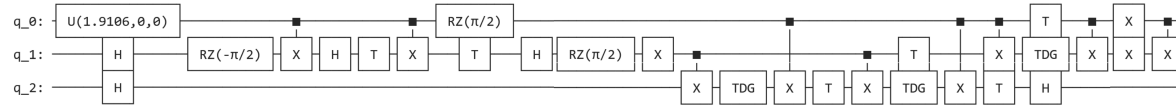


(a) Reference — 19 Gates

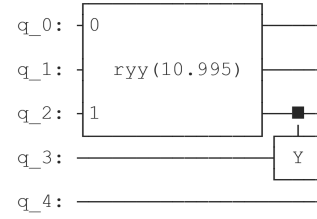


(b) Hybrid (Perfect Accuracy; Seed 202) — 2 Gates

Figure 2: Optimization Example on Problem linearsolver

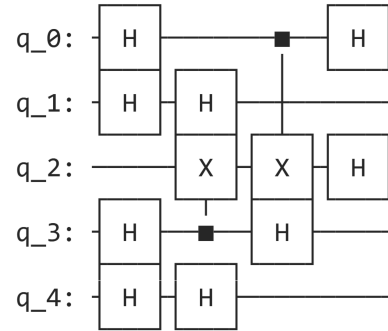


(a) Reference — 32 Gates

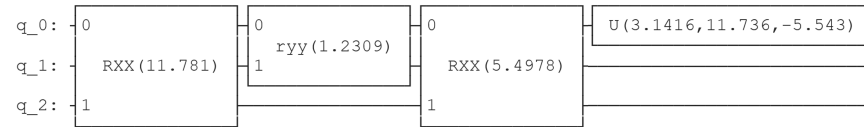


(b) Hybrid (Perfect Accuracy; Seed 6) — 2 Gates

Figure 3: Optimization Example on Problem `1pn.n5`



(a) Reference — 11 Gates



(b) Hybrid (Perfect Accuracy; Seed 114) — 4 Gates

Figure 4: Optimization Example on Problem `wstate.n3`

Table 2: Debugging capabilities given by number of runs per category and use case. (Hybrid/Non-Hybrid/Fixed)

Input State	Problem	RQ1.1 (Perfect Accuracy)				RQ1.2 (Acceptable Accuracy)			
		Optimized	Pareto Equal	Worse	Faulty	Optimized	Pareto Equal	Worse	Faulty
Specific	QG_8 (2 qubits)	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	QSO_6 (2 qubits)	26 / 0 / 0	4 / 30 / 30	0 / 0 / 0	0 / 0 / 0	26 / 0 / 0	4 / 30 / 30	0 / 0 / 0	0 / 0 / 0
	QSO_5 (3 qubits)	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	QSE_15 (4 qubits)	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	QSE_3 (5 qubits)	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
Arbitrary	QSE2_2 (2 qubits)	30 / 0 / 0	0 / 0 / 30	0 / 16 / 0	0 / 14 / 0	30 / 0 / 0	0 / 0 / 30	0 / 0 / 0	0 / 30 / 0
	QSE2_3 (3 qubits)	0 / 0 / 0	17 / 0 / 0	8 / 0 / 8	5 / 30 / 22	14 / 0 / 0	14 / 0 / 0	0 / 0 / 0	2 / 30 / 30
	QSE2_4 (4 qubits)	0 / 0 / 0	0 / 0 / 0	7 / 0 / 0	23 / 30 / 30	1 / 0 / 0	3 / 0 / 0	1 / 0 / 0	25 / 30 / 30
	QSE2_5 (5 qubits)	0 / 0 / 0	0 / 0 / 0	6 / 0 / 0	24 / 30 / 30	0 / 0 / 0	6 / 0 / 0	0 / 0 / 0	24 / 30 / 30

Table 3: Optimization capabilities (summary): number of runs per category, aggregated by input state type and number of qubits. (Hybrid/Non-Hybrid/Fixed)

	RQ2.1 (Perfect Accuracy)				RQ2.2 (Acceptable Accuracy)			
	Optimized	Pareto Equal	Worse	Faulty	Optimized	Pareto Equal	Worse	Faulty
Total	541 / 135 / 105	143 / 84 / 64	50 / 10 / 14	406 / 911 / 957	701 / 493 / 296	78 / 70 / 62	2 / 1 / 0	359 / 576 / 782
Specific	274 / 63 / 45	89 / 84 / 64	23 / 10 / 14	124 / 353 / 387	295 / 229 / 86	68 / 70 / 62	2 / 1 / 0	145 / 210 / 362
Arbitrary	267 / 72 / 60	54 / 0 / 0	27 / 0 / 0	282 / 558 / 570	406 / 264 / 210	10 / 0 / 0	0 / 0 / 0	214 / 366 / 420
2 qubits	135 / 101 / 90	40 / 30 / 30	19 / 0 / 0	16 / 79 / 90	162 / 178 / 150	37 / 30 / 30	0 / 0 / 0	11 / 2 / 30
3 qubits	248 / 17 / 11	37 / 20 / 2	9 / 7 / 14	66 / 316 / 333	289 / 175 / 82	3 / 9 / 2	1 / 0 / 0	67 / 176 / 276
4 qubits	120 / 6 / 2	55 / 32 / 30	14 / 3 / 0	141 / 289 / 298	168 / 84 / 32	36 / 31 / 30	1 / 1 / 0	125 / 214 / 268
5 qubits	38 / 11 / 2	11 / 2 / 2	8 / 0 / 0	183 / 227 / 236	82 / 56 / 32	2 / 0 / 0	0 / 0 / 0	156 / 184 / 208

Table 4: Optimization capabilities (per problem): number of runs per category grouped by number of qubits. Shaded rows represent arbitrary inputs. (Hybrid / Non-Hybrid / Fixed / Q2)

Qubits	Problem	RQ2.1 (Perfect Accuracy)				RQ2.2 (Acceptable Accuracy)			
		Optimized	Pareto Equal	Worse	Faulty	Optimized	Pareto Equal	Worse	Faulty
2 qubits	AA2	30 / 6 / 30	0 / 0 / 0	0 / 0 / 0	0 / 24 / 0	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	GHZ2	0 / 0 / 0	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0
	hamiltonian_2	30 / 7 / 0	0 / 0 / 0	0 / 0 / 0	0 / 23 / 30	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	iswap_n2	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	QFT2	12 / 28 / 0	7 / 0 / 0	10 / 0 / 0	1 / 2 / 30	12 / 28 / 0	7 / 0 / 0	0 / 0 / 0	11 / 2 / 30
	quantum_walk	3 / 0 / 0	3 / 0 / 0	9 / 0 / 0	15 / 30 / 30	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	wstate2	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
3 qubits	AA3	15 / 0 / 0	11 / 0 / 0	0 / 0 / 0	4 / 30 / 30	27 / 0 / 0	0 / 0 / 0	0 / 0 / 0	3 / 30 / 30
	fredkin_n3	6 / 0 / 0	7 / 0 / 0	5 / 0 / 0	12 / 30 / 30	9 / 0 / 0	0 / 0 / 0	0 / 0 / 0	21 / 30 / 30
	GHZ3	30 / 6 / 11	0 / 13 / 1	0 / 6 / 13	0 / 5 / 5	30 / 25 / 11	0 / 5 / 1	0 / 0 / 0	0 / 0 / 18
	GS3	28 / 5 / 0	1 / 7 / 1	1 / 1 / 1	0 / 17 / 28	28 / 21 / 0	1 / 4 / 1	1 / 0 / 0	0 / 5 / 29
	hamiltonian_3	30 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 30 / 30	30 / 18 / 0	0 / 0 / 0	0 / 0 / 0	0 / 12 / 30
	linearsolver_n3	30 / 6 / 0	0 / 0 / 0	0 / 0 / 0	0 / 24 / 30	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	QFT3	0 / 0 / 0	0 / 0 / 0	2 / 0 / 0	28 / 30 / 30	2 / 0 / 0	2 / 0 / 0	0 / 0 / 0	26 / 30 / 30
	quantum_mc_F	13 / 0 / 0	2 / 0 / 0	1 / 0 / 0	14 / 30 / 30	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	teleportation_n3	18 / 0 / 0	5 / 0 / 0	0 / 0 / 0	7 / 30 / 30	19 / 3 / 0	0 / 0 / 0	0 / 0 / 0	11 / 27 / 30
	tofolli_n3	18 / 0 / 0	11 / 0 / 0	0 / 0 / 0	1 / 30 / 30	24 / 0 / 0	0 / 0 / 0	0 / 0 / 0	6 / 30 / 30
	wstate3	30 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 30 / 30	30 / 18 / 0	0 / 0 / 0	0 / 0 / 0	0 / 12 / 30
	wstate_n3	30 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 30 / 30	30 / 30 / 11	0 / 0 / 0	0 / 0 / 0	0 / 0 / 19
4 qubits	AA4	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	30 / 30 / 30	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	adder_n4	3 / 0 / 0	0 / 0 / 0	0 / 0 / 0	27 / 30 / 30	9 / 0 / 0	0 / 0 / 0	0 / 0 / 0	21 / 30 / 30
	bell_n4	30 / 0 / 0	0 / 0 / 0	0 / 0 / 0	0 / 30 / 30	30 / 26 / 0	0 / 0 / 0	0 / 0 / 0	0 / 4 / 30
	cat_state_n4	5 / 2 / 1	3 / 0 / 0	3 / 1 / 0	19 / 27 / 29	5 / 7 / 1	2 / 0 / 0	0 / 0 / 0	23 / 23 / 29
	GHZ4	5 / 2 / 1	3 / 0 / 0	3 / 1 / 0	19 / 27 / 29	5 / 7 / 1	2 / 0 / 0	0 / 0 / 0	23 / 23 / 29
	GS4	13 / 1 / 0	6 / 2 / 0	5 / 1 / 0	6 / 26 / 30	12 / 4 / 0	5 / 1 / 0	1 / 1 / 0	12 / 24 / 30
	hamiltonian_4	23 / 0 / 0	1 / 0 / 0	0 / 0 / 0	6 / 30 / 30	24 / 0 / 0	0 / 0 / 0	0 / 0 / 0	6 / 30 / 30
	hs4_n4	24 / 1 / 0	6 / 0 / 0	0 / 0 / 0	0 / 29 / 30	25 / 5 / 0	0 / 0 / 0	0 / 0 / 0	5 / 25 / 30
	QFT4	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	30 / 30 / 30
	qrng_n4	0 / 0 / 0	27 / 30 / 30	1 / 0 / 0	2 / 0 / 0	0 / 0 / 0	27 / 30 / 30	0 / 0 / 0	3 / 0 / 0
	wstate4	17 / 0 / 0	9 / 0 / 0	2 / 0 / 0	2 / 30 / 30	28 / 5 / 0	0 / 0 / 0	0 / 0 / 0	2 / 25 / 30
5 qubits	AA5	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	30 / 30 / 30	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0
	GHZ5	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	30 / 30 / 30
	GS5	2 / 0 / 0	0 / 0 / 0	3 / 0 / 0	25 / 30 / 30	2 / 0 / 0	0 / 0 / 0	0 / 0 / 0	28 / 30 / 30
	hamiltonian_5	12 / 0 / 0	1 / 0 / 0	0 / 0 / 0	17 / 30 / 30	15 / 0 / 0	1 / 0 / 0	0 / 0 / 0	14 / 30 / 30
	lpn_n5	23 / 11 / 2	3 / 2 / 2	1 / 0 / 0 ₅	3 / 17 / 26	23 / 26 / 2	1 / 0 / 0	0 / 0 / 0	6 / 4 / 28
	qec_en_n5	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	30 / 30 / 30
	QFT5	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	30 / 30 / 30	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0	30 / 30 / 30
	wstate5	1 / 0 / 0	7 / 0 / 0	4 / 0 / 0	18 / 30 / 30	12 / 0 / 0	0 / 0 / 0	0 / 0 / 0	18 / 30 / 30

Table 5: Relative Optimization in per cent (summary)

	RQ2.1 (Perfect Accuracy)			RQ2.2 (Acceptable Accuracy)		
	Gates	Depth	NonLocalGates	Gates	Depth	NonLocalGates
Hybrid	37.0	34.0	18.1	44.6	43.2	30.3
NonHybrid	13.4	13.5	7.4	32.5	31.8	25.1
Fixed	9.1	8.6	2.6	24.8	23.6	17.7
Q2	4.7	3.4	1.3	4.7	3.4	1.3

Table 6: Relative Optimization in per cent (per problem): (Hybrid / Non-Hybrid / Fixed / Q2)

qubits	Problem	RQ2.1 (Perfect Accuracy)			RQ2.2 (Acceptable Accuracy)		
		Gates	Depth	NonLocalGates	Gates	Depth	NonLocalGates
2	AA2	72.7 / 66.7 / 72.7 / —	71.4 / 61.9 / 71.4 / —	0.0 / 0.0 / 0.0 / —	72.7 / 72.7 / 72.7 / —	71.4 / 71.4 / 71.4 / —	0.0 / 0.0 / 0.0 / —
	GHZ2	— / — / — / —	— / — / — / —	— / — / — / —	— / — / — / —	— / — / — / —	— / — / — / —
	QFT2	0.0 / 0.0 / — / —	25.0 / 25.0 / — / —	0.0 / 0.0 / — / —	0.0 / 0.0 / — / —	25.0 / 25.0 / — / —	0.0 / 0.0 / — / —
	hamiltonian_2	66.7 / 23.8 / — / —	66.7 / 28.6 / — / —	50.0 / 28.6 / — / —	66.7 / 44.4 / 61.1 / —	66.7 / 38.3 / 58.3 / —	50.0 / 50.0 / 25.0 / —
	iswap_n2	77.0 / 77.8 / 77.8 / —	71.0 / 71.4 / 71.4 / —	50.0 / 50.0 / 50.0 / —	77.0 / 77.8 / 77.8 / —	71.0 / 71.4 / 71.4 / —	50.0 / 50.0 / 50.0 / —
	quantum_walk	36.4 / — / — / —	14.3 / — / — / —	11.1 / — / — / —	81.8 / 81.8 / 81.8 / —	85.7 / 85.7 / 71.4 / —	100.0 / 100.0 / 100.0 / —
	wstate2	58.0 / 40.0 / 40.0 / —	50.0 / 50.0 / 50.0 / —	50.0 / 50.0 / 50.0 / —	58.0 / 40.0 / 40.0 / —	50.0 / 50.0 / 50.0 / —	50.0 / 50.0 / 50.0 / —
3	AA3	61.8 / — / — / 13.8	50.4 / — / — / 12.5	7.8 / — / — / 0.0	63.0 / — / — / 13.8	54.9 / — / — / 12.5	21.0 / — / — / 0.0
	GHZ3	33.3 / 33.3 / 24.2 / —	33.3 / 33.3 / 33.3 / —	0.0 / 0.0 / 0.0 / —	33.3 / 33.3 / 24.2 / —	33.3 / 33.3 / 33.3 / —	0.0 / 0.0 / 0.0 / —
	GS3	44.0 / 23.3 / — / —	24.1 / 10.0 / — / —	31.0 / 6.7 / — / —	42.9 / 20.6 / — / —	24.1 / 8.3 / — / —	33.3 / 30.2 / — / —
	QFT3	— / — / — / —	— / — / — / —	— / — / — / —	0.0 / — / — / —	25.0 / — / — / —	25.0 / — / — / —
	fredkin_n3	37.7 / — / — / —	16.7 / — / — / —	12.5 / — / — / —	37.4 / — / — / —	14.1 / — / — / —	11.1 / — / — / —
	hamiltonian_3	62.4 / — / — / —	64.1 / — / — / —	46.7 / — / — / —	62.0 / 46.7 / — / —	63.3 / 46.3 / — / —	48.3 / 48.6 / — / —
	linearsolver_n3	87.9 / 76.3 / — / 21.1	81.2 / 66.7 / — / 0.0	73.3 / 70.8 / — / 0.0	87.7 / 79.1 / 84.2 / 21.1	80.9 / 72.1 / 81.8 / 0.0	75.0 / 76.7 / 75.0 / 0.0
	quantum_mc.F	61.5 / — / — / 34.1	63.2 / — / — / 53.1	51.4 / — / — / 50.0	95.1 / 94.9 / 95.1 / 34.1	96.4 / 93.4 / 93.8 / 53.1	100.0 / 99.6 / 100.0 / 50.0
	teleportation_n3	40.3 / — / — / —	51.9 / — / — / —	0.0 / — / — / —	39.5 / 20.8 / — / —	50.9 / 27.8 / — / —	0.0 / 0.0 / — / —
	tofolli_n3	54.3 / — / — / —	48.1 / — / — / —	10.2 / — / — / —	47.7 / — / — / —	44.8 / — / — / —	15.3 / — / — / —
	wstate3	50.0 / — / — / —	34.4 / — / — / —	21.7 / — / — / —	49.3 / 31.5 / — / —	33.3 / 23.1 / — / —	24.2 / 23.6 / — / —
	wstate_n3	84.6 / — / — / 3.3	82.3 / — / — / 0.0	66.7 / — / — / 0.0	84.6 / 79.8 / 81.8 / 3.3	82.3 / 78.6 / 79.8 / 0.0	66.7 / 66.3 / 70.7 / 0.0
4	AA4	— / — / — / 12.1	— / — / — / 19.0	— / — / — / 0.0	93.9 / 93.9 / 93.9 / 12.1	95.2 / 93.8 / 90.5 / 19.0	100.0 / 100.0 / 100.0 / 0.0
	GHZ4	10.0 / 12.5 / 25.0 / —	35.0 / 37.5 / 25.0 / —	0.0 / 0.0 / 0.0 / —	10.0 / 21.4 / 25.0 / —	35.0 / 46.4 / 25.0 / —	0.0 / 0.0 / 0.0 / —
	GS4	23.1 / 12.5 / — / —	9.6 / 0.0 / — / —	17.3 / 25.0 / — / —	22.9 / 15.6 / — / —	10.4 / 12.5 / — / —	20.8 / 25.0 / — / —
	QFT4	— / — / — / —	— / — / — / —	— / — / — / —	— / — / — / —	— / — / — / —	— / — / — / —
	adder_n4	21.7 / — / — / —	9.1 / — / — / —	20.0 / — / — / —	34.8 / — / — / —	23.2 / — / — / —	40.0 / — / — / —
	bell_n4	73.6 / — / — / —	63.1 / — / — / —	44.8 / — / — / —	73.3 / 81.0 / — / —	63.6 / 75.4 / — / —	51.0 / 67.6 / — / —
	cat_state_n4	10.0 / 12.5 / 25.0 / —	35.0 / 37.5 / 25.0 / —	0.0 / 0.0 / 0.0 / —	10.0 / 21.4 / 25.0 / —	35.0 / 46.4 / 25.0 / —	0.0 / 0.0 / 0.0 / —
	hamiltonian_4	51.1 / — / — / —	58.7 / — / — / —	39.9 / — / — / —	48.0 / — / — / —	58.0 / — / — / —	44.4 / — / — / —
	hs4_n4	69.6 / 57.1 / — / 42.9	56.9 / 55.6 / — / 22.2	29.2 / 50.0 / — / 0.0	68.6 / 60.0 / — / 42.9	56.4 / 51.1 / — / 22.2	34.0 / 35.0 / — / 0.0
	qrng_n4	— / — / — / —	— / — / — / —	— / — / — / —	— / — / — / —	— / — / — / —	— / — / — / —
	wstate4	39.8 / — / — / —	25.0 / — / — / —	8.8 / — / — / —	45.6 / 44.6 / — / —	32.1 / 17.5 / — / —	24.4 / 30.0 / — / —
	AA5	— / — / — / 7.5	— / — / — / 10.8	— / — / — / 0.0	96.2 / 96.2 / 96.2 / 7.5	97.3 / 96.0 / 94.6 / 10.8	100.0 / 100.0 / 100.0 / 0.0
5	GHZ5	— / — / — / —	— / — / — / —	— / — / — / —	— / — / — / —	— / — / — / —	— / — / — / —
	GS5	30.0 / — / — / —	30.0 / — / — / —	0.0 / — / — / —	30.0 / — / — / —	30.0 / — / — / —	0.0 / — / — / —
	QFT5	— / — / — / —	— / — / — / —	— / — / — / —	— / — / — / —	— / — / — / —	— / — / — / —
	hamiltonian_5	41.7 / — / — / —	56.7 / — / — / —	31.2 / — / — / —	36.5 / — / — / —	54.7 / — / — / —	33.3 / — / — / —
	lpn_n5	77.5 / 73.6 / 81.8 / 36.4	44.6 / 34.1 / 50.0 / 0.0	0.0 / 0.0 / 0.0 / 0.0	77.5 / 78.7 / 81.8 / 36.4	44.6 / 43.3 / 50.0 / 0.0	0.0 / 0.0 / 0.0 / 0.0
	qec_en_n5	— / — / — / 8.0	— / — / — / 11.8	— / — / — / 0.0	— / — / — / 8.0	— / — / — / 11.8	— / — / — / 0.0
	wstate5	29.4 / — / — / —	20.0 / — / — / —	12.5 / — / — / —	48.0 / — / — / —	33.3 / — / — / —	34.4 / — / — / —

Table 7: Effects of search configurations: number of runs per category (Optimized / Pareto-equal / Worse / Faulty), aggregated by use case type, input state type, and number of qubits

(a) Perfect Accuracy

	Hybrid	NGen=50	NGen=100	N=100	N=200	Init=20	Q2
Total	717/164/71/458	523/191/95/601	653/175/81/501	868/181/56/305	915/187/59/249	874/453/31/52	776/152/39/443
Repair	176/21/21/52	162/28/24/56	170/26/20/54	180/34/25/31	180/38/34/18	176/21/21/52	178/21/21/50
Optimization	541/143/50/406	361/163/71/545	483/149/61/447	688/147/31/274	735/149/25/231	698/432/10/0	598/131/18/393
Specific	420/93/23/124	353/101/33/173	397/96/31/136	488/95/14/63	506/100/11/43	501/159/0/0	447/90/8/115
Arbitrary	297/71/48/334	170/90/62/428	256/79/50/365	380/86/42/242	409/87/48/206	373/294/31/52	329/62/31/328
2 qubits	221/44/19/16	195/52/28/25	209/50/20/21	240/45/11/4	245/46/8/1	241/49/10/0	233/41/9/17
3 qubits	278/54/17/71	205/58/29/128	256/57/19/88	315/62/7/36	335/56/6/23	286/121/8/5	299/47/8/66
4 qubits	150/55/21/164	80/73/29/208	130/57/30/173	217/55/17/101	231/52/18/89	197/163/7/23	180/47/12/151
5 qubits	68/11/14/207	43/8/9/240	58/11/12/219	96/19/21/164	104/33/27/136	150/120/6/24	64/17/10/209

(b) Acceptable Accuracy

	Hybrid	NGen=50	NGen=100	N=100	N=200	Init=20	Q2
Total	892/105/3/410	683/102/4/621	820/102/5/483	1055/129/0/226	1111/121/1/177	988/370/1/51	953/79/2/376
Repair	191/27/1/51	165/31/3/71	181/29/2/58	206/53/0/11	228/40/0/2	191/27/1/51	209/9/2/50
Optimization	701/78/2/359	518/71/1/550	639/73/3/425	849/76/0/215	883/81/1/175	797/343/0/0	744/70/0/326
Specific	441/72/2/145	371/78/3/208	416/74/2/168	512/68/0/80	526/70/1/63	502/158/0/0	463/68/0/129
Arbitrary	451/33/1/265	312/24/1/413	404/28/3/315	543/61/0/146	585/51/0/114	486/212/1/51	490/11/2/247
2 qubits	248/41/0/11	226/49/2/23	239/46/0/15	266/34/0/0	270/30/0/0	259/41/0/0	260/34/0/6
3 qubits	333/17/1/69	245/18/2/155	303/19/3/95	373/12/0/35	394/8/0/18	319/99/0/2	351/6/2/61
4 qubits	199/39/2/150	134/31/0/225	181/33/1/175	263/56/0/71	286/59/0/45	230/134/1/25	229/38/0/123
5 qubits	112/8/0/180	78/4/0/218	97/4/1/198	153/27/0/120	161/24/1/114	180/96/0/24	113/1/0/186

Table 8: Comparison of Search settings: Perfect Accuracy

qubits	Problem	Hybrid	NGen=50	NGen=100	N=100	N=200	Init=20	Q2
2 qubits	AA2	30/0/0/0	29/1/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	GHZ2	0/30/0/0	0/30/0/0	0/30/0/0	0/30/0/0	0/30/0/0	0/30/0/0	0/30/0/0
	QFT2	12/7/10/1	4/3/17/6	9/6/11/4	27/3/0/0	30/0/0/0	23/7/0/0	22/2/6/0
	QG_8	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	QSE2.2	30/0/0/0	25/5/0/0	29/1/0/0	30/0/0/0	30/0/0/0	30/0/0/0	29/1/0/0
	QSO.6	26/4/0/0	17/11/2/0	21/9/0/0	29/1/0/0	30/0/0/0	26/4/0/0	29/1/0/0
	hamiltonian_2	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	iswap_n2	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	quantum_walk	3/3/9/15	0/2/9/19	0/4/9/17	4/11/11/4	5/16/8/1	12/8/10/0	3/7/3/17
	wstate2	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
3 qubits	AA3	15/11/0/4	0/11/1/18	11/12/1/6	14/13/1/2	16/14/0/0	13/17/0/0	19/10/0/1
	GHZ3	30/0/0/0	22/2/4/2	27/2/1/0	30/0/0/0	30/0/0/0	16/14/0/0	30/0/0/0
	GS3	28/1/1/0	24/2/3/1	26/2/1/1	30/0/0/0	30/0/0/0	25/5/0/0	30/0/0/0
	QFT3	0/0/2/28	0/0/1/29	0/0/2/28	0/1/1/28	2/1/6/21	0/30/0/0	0/0/1/29
	QSE2.3	0/17/8/5	0/12/10/8	0/16/7/7	1/28/1/0	0/30/0/0	0/17/8/5	0/19/7/4
	QSO.5	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	fredkin_n3	6/7/5/12	0/4/2/24	3/5/4/18	13/10/4/3	23/7/0/0	1/29/0/0	9/10/0/11
	hamiltonian_3	30/0/0/0	23/3/0/4	29/0/0/1	30/0/0/0	30/0/0/0	30/0/0/0	29/1/0/0
	linearsolver_n3	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	quantum_mc.F	13/2/1/14	4/2/0/24	10/2/1/17	21/6/0/3	28/0/0/2	28/2/0/0	16/0/0/14
	teleportation_n3	18/5/0/7	11/4/4/11	15/6/2/7	29/1/0/0	30/0/0/0	29/1/0/0	26/1/0/3
	tofolli_n3	18/11/0/1	4/15/4/7	16/11/0/3	27/3/0/0	26/4/0/0	24/6/0/0	20/6/0/4
	wstate3	30/0/0/0	27/3/0/0	29/1/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	wstate_n3	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	AA4	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	25/5/0/0	0/0/0/30
4 qubits	GHZ4	5/3/3/19	3/1/3/23	5/1/4/20	20/4/1/5	28/1/1/0	8/22/0/0	12/3/1/14
	GS4	13/6/5/6	4/10/5/11	10/7/4/9	23/6/1/0	23/6/1/0	25/5/0/0	19/5/1/5
	QFT4	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	0/30/0/0	0/0/0/30
	QSE2.4	0/0/7/23	0/0/6/24	0/0/7/23	0/5/13/12	0/5/15/10	0/0/7/23	0/0/8/22
	QSE.15	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	adder_n4	3/0/0/27	0/0/0/30	1/0/0/29	10/2/0/18	9/2/0/19	2/28/0/0	3/1/0/26
	bell_n4	30/0/0/0	23/7/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	cat_state_n4	5/3/3/19	3/1/3/23	5/1/4/20	20/4/1/5	28/1/1/0	11/19/0/0	12/3/1/14
	hamiltonian_4	23/1/0/6	6/5/2/17	21/1/0/8	30/0/0/0	30/0/0/0	22/8/0/0	26/0/0/4
	hs4_n4	24/6/0/0	4/23/0/3	16/14/0/0	28/2/0/0	29/1/0/0	14/16/0/0	28/2/0/0
	qrng_n4	0/27/1/2	0/21/4/5	0/24/4/2	0/30/0/0	0/30/0/0	0/30/0/0	0/29/0/1
	wstate4	17/9/2/2	7/5/6/12	12/9/7/2	26/2/1/1	24/6/0/0	30/0/0/0	20/4/1/5
	AA5	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	22/8/0/0	0/0/0/30
	GHZ5	0/0/0/30	0/0/0/30	0/0/0/30	3/0/2/25	1/4/0/25	5/25/0/0	0/0/1/29
	GS5	2/0/3/25	0/0/1/29	1/0/2/27	4/3/3/20	1/8/8/13	30/0/0/0	1/2/3/24
5 qubits	QFT5	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	0/30/0/0	0/0/0/30
	QSE2.5	0/0/6/24	0/0/6/24	0/0/6/24	0/0/11/19	0/3/19/8	0/0/6/24	0/0/6/24
	QSE.3	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	hamiltonian_5	12/1/0/17	0/0/0/30	6/1/0/23	26/1/0/3	30/0/0/0	6/24/0/0	9/2/0/19
	lpn_n5	23/3/1/3	13/8/1/8	21/4/1/4	28/2/0/0	30/0/0/0	26/4/0/0	22/7/0/1
	qec_en_n5	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	1/4/0/25	2/28/0/0	0/0/0/30
	wstate5	1/7/4/18	0/0/1/29	0/6/3/21	5/13/5/7	11/14/0/5	29/1/0/0	2/6/0/22

Table 9: Comparison of Search settings: Acceptable Accuracy

qubits	Problem	Hybrid	NGen=50	NGen=100	N=100	N=200	Init=20	Q2
2 qubits	AA2	30/0/0/0	29/1/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	GHZ2	0/30/0/0	0/30/0/0	0/30/0/0	0/30/0/0	0/30/0/0	0/30/0/0	0/30/0/0
	QFT2	12/7/10/1	4/3/17/6	9/6/11/4	27/3/0/0	30/0/0/0	23/7/0/0	22/2/6/0
	QG_8	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	QSE2.2	30/0/0/0	25/5/0/0	29/1/0/0	30/0/0/0	30/0/0/0	30/0/0/0	29/1/0/0
	QSO.6	26/4/0/0	17/11/2/0	21/9/0/0	29/1/0/0	30/0/0/0	26/4/0/0	29/1/0/0
	hamiltonian_2	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	iswap_n2	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	quantum_walk	0/0/0/30	0/2/9/19	0/4/9/17	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30
	wstate2	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
3 qubits	AA3	15/1/0/14	0/11/1/18	11/12/1/6	13/1/0/16	17/0/0/13	11/9/0/10	16/0/0/14
	GHZ3	30/0/0/0	22/2/4/2	27/2/1/0	30/0/0/0	30/0/0/0	16/14/0/0	30/0/0/0
	GS3	28/1/1/0	24/2/3/1	26/2/1/1	30/0/0/0	30/0/0/0	24/6/0/0	30/0/0/0
	QFT3	0/0/0/30	0/0/1/29	0/0/2/28	0/0/1/29	0/0/2/28	0/23/0/7	0/0/0/30
	QSE2.3	0/10/1/19	0/12/10/8	0/16/7/7	0/3/0/27	0/0/0/30	0/10/1/19	0/3/3/24
	QSO.5	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	fredkin_n3	5/2/1/22	0/4/2/24	3/5/4/18	10/2/1/17	19/2/0/9	0/29/0/1	7/1/0/22
	hamiltonian_3	30/0/0/0	23/3/0/4	29/0/0/1	30/0/0/0	30/0/0/0	29/0/0/1	29/0/0/1
	linearsolver_n3	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	quantum_mc.F	0/0/0/30	4/2/0/24	10/2/1/17	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30
	teleportation_n3	19/4/0/7	11/4/4/11	15/6/2/7	30/0/0/0	30/0/0/0	30/0/0/0	26/1/0/3
	tofolli_n3	19/1/0/10	4/15/4/7	16/11/0/3	24/0/0/6	26/0/0/4	29/0/0/1	18/1/0/11
	wstate3	29/0/0/1	27/3/0/0	29/1/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	wstate_n3	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	AA4	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30
4 qubits	GHZ4	5/3/3/19	3/1/3/23	5/1/4/20	20/4/1/5	28/0/2/0	8/22/0/0	12/3/1/14
	GS4	12/7/5/6	4/10/5/11	10/7/4/9	23/5/2/0	22/8/0/0	25/5/0/0	19/5/1/5
	QFT4	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	0/12/0/18	0/0/0/30
	QSE2.4	0/0/2/28	0/0/6/24	0/0/7/23	0/2/3/25	0/0/0/30	0/0/2/28	0/0/3/27
	QSE.15	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	adder_n4	2/0/0/28	0/0/0/30	1/0/0/29	6/1/0/23	8/2/0/20	2/27/0/1	2/0/0/28
	bell_n4	27/0/0/3	23/7/0/0	30/0/0/0	29/0/0/1	30/0/0/0	28/0/0/2	30/0/0/0
	cat_state_n4	5/3/3/19	3/1/3/23	5/1/4/20	20/4/1/5	28/0/2/0	11/19/0/0	12/3/1/14
	hamiltonian_4	23/0/0/7	6/5/2/17	21/1/0/8	30/0/0/0	30/0/0/0	18/6/0/6	25/0/0/5
	hs4_n4	25/4/0/1	4/23/0/3	16/14/0/0	30/0/0/0	30/0/0/0	24/6/0/0	28/2/0/0
	qrng_n4	0/27/1/2	0/21/4/5	0/24/4/2	0/30/0/0	0/30/0/0	0/30/0/0	0/29/0/1
	wstate4	12/0/0/18	7/5/6/12	12/9/7/2	20/0/0/10	20/0/0/10	30/0/0/0	18/1/0/11
	AA5	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30
	GHZ5	0/0/0/30	0/0/0/30	0/0/0/30	3/0/2/25	1/4/0/25	5/25/0/0	0/0/1/29
	GS5	2/0/3/25	0/0/1/29	1/0/2/27	4/3/3/20	1/6/9/14	30/0/0/0	2/1/3/24
5 qubits	QFT5	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	0/8/0/22	0/0/0/30
	QSE2.5	0/0/1/29	0/0/6/24	0/0/6/24	0/0/0/30	0/0/0/30	0/0/1/29	0/0/1/29
	QSE.3	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0	30/0/0/0
	hamiltonian_5	10/1/0/19	0/0/0/30	6/1/0/23	18/2/0/10	28/0/0/2	6/20/0/4	7/1/0/22
	lpn_n5	23/3/1/3	13/8/1/8	21/4/1/4	28/2/0/0	30/0/0/0	30/0/0/0	22/7/0/1
	qec_en_n5	0/0/0/30	0/0/0/30	0/0/0/30	0/0/0/30	1/3/0/26	2/28/0/0	0/0/0/30
	wstate5	0/1/0/29	0/0/1/29	0/6/3/21	2/0/0/28	3/1/0/26	27/3/0/0	1/1/0/28

Table 10: Analysis of Performance Indicators

(a) Comparison of PIs for Hybrid, Non-Hybrid, Fixed.

Analysis using Wilcoxon signed-rank test, effect sizes using Vargha-Delaney \hat{A}_{12}

PI Comparison		DCI	HV	IGD ⁺
All	Hybrid vs. Non-Hybrid	✓✓	✓	✗
	Hybrid vs. Fixed	✓✓✓	✓	≡
	Non-Hybrid vs. Fixed	✓✓	✓	≡
Repair	Hybrid vs. Non-Hybrid	✓✓✓	✓	≡
	Hybrid vs. Fixed	✓✓	✓	✓✓
	Non-Hybrid vs. Fixed	≡	≡	≡
Optimize	Hybrid vs. Non-Hybrid	✓✓	≡	✗
	Hybrid vs. Fixed	✓✓✓	✓✓	✗
	Non-Hybrid vs. Fixed	✓✓✓	✓	≡
Specific	Hybrid vs. Non-Hybrid	≡	≡	≡
	Hybrid vs. Fixed	✓✓✓	✓	≡
	Non-Hybrid vs. Fixed	✓✓✓	✓	≡
Arbitrary	Hybrid vs. Non-Hybrid	✓✓✓	✓	✗✗
	Hybrid vs. Fixed	✓✓✓	✓✓	≡
	Non-Hybrid vs. Fixed	✓	≡	≡

(b) Legend for interpretation of the results in the tables.

Symbol	Meaning	Symbol	Meaning	Symbol	Meaning
✗	Negligibly Worse	≡	Equal	✓	Negligibly Better
✗	Slightly Worse			✓	Slightly Better
✗✗	Moderately Worse			✓✓	Moderately Better
✗✗✗	Largely Worse			✓✓✓	Largely Better