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
[Tomesh 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

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

		RQ1.1 (Perfect Accuracy)				RQ1.2 (Acceptable Accuracy)			
Input State	Problem	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)

		RQ2.1 (Perfect Accuracy)				RQ2.2 (Acceptable Accuracy)			
Qubits	Problem	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	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
Non`Hybrid`	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) Gates	RQ2.1 (Perfect Accuracy) Depth	RQ2.1 (Perfect Accuracy) NonLocalGates	RQ2.2 (Acceptable Accuracy) Gates	RQ2.2 (Acceptable Accuracy) Depth	RQ2.2 (Acceptable Accuracy) 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 / — / —
5	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
	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
4 qubits	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
	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	0/30/0/0	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
5 qubits	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
	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
4 qubits	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
	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
5 qubits	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
	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) 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

(b) 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`	✓	≡	≡