Faster and Better Quantum Software Testing through Specification Reduction and Projective Measurements

Appendix

NOAH H. OLDFIELD, Simula Research Laboratory and University of Oslo, Norway
CHRISTOPH LAABER, Simula Research Laboratory, Norway
TAO YUE, Simula Research Laboratory, Norway
SHAUKAT ALI, Simula Research Laboratory, Norway and Oslo Metropolitan University, Norway

1 Introduction

This appendix provides supplementary details for the TOSEM paper titled "Faster and Better Quantum Software Testing through Specification Reduction and Projective Measurements."

2 Example A

Given the state vector:

$$\frac{1}{\sqrt{8}}\Big(|00000\rangle + |00010\rangle + |00100\rangle - |00110\rangle + |01000\rangle + |01010\rangle - |01100\rangle + |01110\rangle \Big) \tag{1}$$

The following reduced state can not be found with the Greedy approach:

$$\frac{1}{\sqrt{4}}\Big(|0+++0\rangle + |0+-+0\rangle + |0-+-0\rangle - |0---0\rangle \Big) \tag{2}$$

Demonstration: Let's look at the reduced state resulting from a Hadamard gate applied to the second, third and fourth qubits:

$$|\psi\rangle_{ihiii} = \frac{1}{2}\Big(|0+000\rangle + |0+010\rangle + |0-100\rangle - |0-110\rangle \Big) \tag{3}$$

$$|\psi\rangle_{iihii} = \frac{1}{2}\Big(|00+00\rangle + |00-10\rangle + |01-00\rangle + |01+10\rangle \Big) \tag{4}$$

$$|\psi\rangle_{iihi} = \frac{1}{2}\Big(|000+0\rangle + |001-0\rangle + |010+0\rangle - |011-0\rangle \Big) \tag{5}$$

None of these states are possible to find with the Greedy algorithm, as we can only progress with Greedy further with either a reduction or an increase in the number of basis states. Thus, neither options can lead to finding the state Eq. (2), because only reduction is allowed further.

3 Theoretical Runtime of Reduction Algorithm

We quantify the theoretical runtime of Algorithm 1 by the number of basis transformations required to reduce a given program specification (PS). An exhaustive search to find the global minimum of the rank, ($N_{\texttt{psPrevious}}$ from Algorithm 1), will at most need to sample all possible basis transformations, one for each choice of the values $x_0, x_1, \cdots, x_{n-1}$, in the

Authors' addresses: Noah H. Oldfield, Simula Research Laboratory and University of Oslo, Oslo, Norway, noah@simula.no; Christoph Laaber, Simula Research Laboratory, Oslo, Norway, laaber@simula.no; Tao Yue, Simula Research Laboratory, Oslo, Norway, taoyue@gmail.com; Shaukat Ali, Simula Research Laboratory, Oslo, Norway and Oslo Metropolitan University, Oslo, Norway, shaukat@simula.no.

basis transformation Eq. (8) (n = `#Qubits`). Therefore, exhaustive search requires $O(2^n)$ basis transformations to find the global minimum.

Our Greedy reduction algorithm, finds a local or global minimum with $O(n^2)$ number of basis transformations. We demonstrate this theoretical runtime by considering a few iterations of Algorithm 1. In the first iteration of the "Basis Change" stage, there are n possible positions for the single-qubit Hadamard gate. If we find a reduction and proceed to the next iteration, there are now $n-1$ possible transformations, as we fixed the gate in the first iteration. Subsequently, if we find another reduction, there are $n-2$ possibilities, and so on until there is only one final choice for the last Hadamard gate. Therefore, the upper bound of the number of basis transformations for the Greedy algorithm is equal to the series of consecutive natural numbers:

$$f(n) = n + (n-1) + (n-2) + \cdots + 1 = \frac{n(n+1)}{2} \tag{6}$$

In Eq. (6), we compute the maximum number of objective function evaluations $f(n)$ required by our Greedy approach in order to obtain a reduction.

4 Detailed Sampling Strategies

Here, we provide additional details sampling strategies for our 4 program categories: Grover Search (Grov), Quantum Walk (Qwalk), Various (Var) and Graph States (Gs).

4.1 Grov

In order to successfully apply the reflection about the mean operation of the Grover operator, the set M, defining the number of matching entries in the search space, must be of size $M < 2^n/2$, where n is the number of qubits [2]. We generate program variations by first specifying a range of qubit values, and then for a fixed number of qubits, we specify a set of output states between 0 and $N-1$, with $N = 2^n$, which are to be amplified. We then iterate over set sizes M up to $M = N-2$ with an increment determined by $N-2/2$ divided by the number of program variations within each qubit. We exclude $N-1$ because setting the boundary at $N-1$ makes the increment an integer, avoiding rounding. We then randomly select output states in the set as we iterate over different set sizes. When the qubit and input set are specified, we maximize the output criterion Eq. (5) by performing repeated iterations of the Grover operator until the probability amplitudes of states outside the input set reach an order of magnitude of 10^{-4}. When M is very small compared to N, the optimal number of iterations is approximately given by $\pi/4\sqrt{N/M}$ [2].

4.2 Gs

Graph states are representations of a graph $G = (V, E)$ where the set of vertices V of the graph are encoded as quantum states [1, 3]. The quantum program for creating a graph state for a given graph works by initializing all states to zero. Then, we apply a Hadamard gate to every qubit in the register, yielding a uniform superposition. Lastly, a controlled Z gate is applied between all pairs of vertices (a, b) that connect to an edge from the set E for all edges. Due to this program structure, the Gs programs are low depth, but the combination of Hadamard and controlled Z gates always results in 2^{n-2} number of output states, which makes Gs programs a reliable sample of programs with a high number of output states.

Our sampling strategy for generating Gs program variations consists of defining the type of graph of our graph state program by defining the set of edges E provided to the program. Given a qubit count n, the set of edges consists of pairs

of indices (k, l) where $k \neq l$ and both are selected from the set $\{0, 1, \cdots, n-1\}$. With respect to our testing runtime constraints and to maximize the output criterion Eq. (2), we select one type of graph, namely the ring graph, which consists of the edge set $E = \{(0, 1), (1, 2), \cdots, (n-1, 0)\}$.

4.3 Qwalk

Quantum walks are the quantum counterpart of classical random walks, utilizing principles of superposition and interference. Unlike classical walks that model probabilistic movement in space, quantum walks operate with a "walker" in a superposed state, moving through positions based on a quantum coin's state. The walker's position is represented by a set of qubits, with each qubit encoding different potential positions. An additional qubit, the quantum coin, is manipulated using a Hadamard gate to create a superposition state. This state influences the walker's movement, controlled through gates such as $CNOT$ and multi-controlled $CNOT$. The walker's movement in a quantum walk is stepwise, determined by the coin qubit's state. At the end of the walk, measuring the qubits yields the probability distribution of the walker's positions. Quantum walks enable efficient exploration of complex structures and offer advantages in computation and simulation over some classical methods [6].

We select quantum walk programs for qubits ranging from 5 to 8. Then, for varying degrees of walks, the final state vector spreads out more or less, leading to a varying saturation of the output criterion Eq. (5). Thus, we select program variations within each qubit number automatically by varying the number of walks performed in the respective program.

4.4 Var

We select programs from the Var category by visually inspecting the final state vectors of the programs using the QCengine API from the original source of the programs [5]. The programs are denoted by *Example* x/y where x and y refers to example number y of chapter x. From the 52 programs of the program source, we select a sample of programs that maximize the output criterion Eq. (5) after we apply the following exclusion criteria. We exclude programs that are simple demonstrational programs, such as the program Example 2-1, which simulates a random bit. Thus, we exclude the programs Examples: 2-1, 2-2, 2-3 and 3-1. Next, we exclude programs that only contain a single output state prior to measurement, as at least two output states are required for reduction. This excludes the programs Examples: 3-4, 5-6, 10-2, 12-2, 12-4, 14-GT, 14-BV and 14-S. Next, we exclude programs for runtime constraints as they contain a relatively high number of qubits combined with a high depth, such as Example 4-2 with 30 qubits. We exclude the following programs Example: 4-2, 11-2, 11-4, 11-6, 12-1. After performing these exclusions, we select a sample of programs where the output criterion is maximized, yielding the programs that we list in Table 3. For each program, we generate 4 program variations by varying the input state between 0-3. For further program descriptions, we refer to the source [4].

5 Results

Here, we show detailed tables of our results for RQ1, RQ2, and RQ3. All tables contain pairwise statistical tests between the Greedy approach and Random baseline for a given row, which are described in the full paper.

5.1 RQ1 Tables

In Tables 1 to 8, we provide the reduction rate and runtime results for RQ1 by category and by qubit count. The **Greedy** and **Random** columns depict the reduction rate percentage and the reduction runtime in milliseconds. The three rightmost columns show the pairwise statistical Mann-Whitney U (MWU) tests between the Greedy and Random

Table 1. Reduction rate results for the **Grov** program category.

ID	Category	#Qubits	Depth	Greedy [%]	Random [%]	p-value	$\hat{A}_{12}$	Magnitude
0	**Grov**	**6**	**178**	**72.4 ± 9.6**	**56.0 ± 1.8**	**3.6e-27**	**0.873**	**(L)**
1	Grov	6	30	65.6 ± 0.0	65.6 ± 0.0	1.0	0.5	(N)
2	Grov	6	121	68.8 ± 0.0	66.4 ± 5.9	1.1e-04	0.57	(N)
3	**Grov**	**6**	**42**	**60.9 ± 6.6**	**58.8 ± 4.6**	**4.6e-07**	**0.698**	**(M)**
4	Grov	6	48	60.8 ± 7.9	59.5 ± 8.5	0.29283	0.538	(N)
5	Grov	6	54	56.9 ± 5.9	57.2 ± 5.1	0.98945	0.499	(N)
6	**Grov**	**6**	**66**	**59.4 ± 0.0**	**55.7 ± 5.6**	**1.1e-13**	**0.72**	**(M)**
7	**Grov**	**6**	**72**	**75.0 ± 0.0**	**63.2 ± 5.1**	**2.2e-41**	**1.0**	**(L)**
8	**Grov**	**6**	**78**	**65.6 ± 0.0**	**60.2 ± 2.8**	**6.0e-40**	**1.0**	**(L)**
9	**Grov**	**6**	**125**	**96.9 ± 0.0**	**91.4 ± 3.0**	**1.3e-40**	**1.0**	**(L)**
10	Grov	6	90	61.9 ± 6.0	64.0 ± 2.1	1.0	0.5	(N)
11	**Grov**	**7**	**57**	**75.1 ± 8.6**	**65.6 ± 0.0**	**3.7e-18**	**0.775**	**(L)**
12	**Grov**	**7**	**36**	**68.7 ± 6.6**	**65.6 ± 0.0**	**9.3e-06**	**0.59**	**(S)**
13	**Grov**	**7**	**48**	**78.9 ± 0.8**	**76.2 ± 3.3**	**1.3e-18**	**0.81**	**(L)**
14	**Grov**	**7**	**205**	**60.9 ± 0.0**	**56.4 ± 2.9**	**1.6e-39**	**1.0**	**(L)**
15	**Grov**	**7**	**492**	**62.5 ± 0.0**	**60.3 ± 3.5**	**1.5e-18**	**0.785**	**(L)**
16	**Grov**	**7**	**96**	**60.9 ± 0.0**	**59.3 ± 2.8**	**5.1e-11**	**0.68**	**(M)**
17	**Grov**	**7**	**108**	**71.9 ± 0.0**	**64.5 ± 6.8**	**2.8e-19**	**0.795**	**(L)**
18	**Grov**	**7**	**120**	**68.8 ± 0.0**	**57.1 ± 2.9**	**1.1e-39**	**1.0**	**(L)**
19	**Grov**	**7**	**132**	**64.1 ± 0.0**	**60.1 ± 4.9**	**6.3e-16**	**0.75**	**(L)**
20	**Grov**	**7**	**144**	**62.5 ± 4.4**	**56.0 ± 3.7**	**8.5e-23**	**0.874**	**(L)**
21	**Grov**	**7**	**156**	**58.7 ± 0.8**	**57.4 ± 3.4**	**3.6e-04**	**0.632**	**(S)**
22	**Grov**	**8**	**79**	**81.0 ± 5.7**	**76.6 ± 0.0**	**8.5e-12**	**0.69**	**(M)**
23	**Grov**	**8**	**54**	**73.4 ± 3.6**	**68.7 ± 0.2**	**4.4e-28**	**0.896**	**(L)**
24	**Grov**	**8**	**84**	**65.1 ± 2.6**	**61.2 ± 2.0**	**2.4e-21**	**0.852**	**(L)**
25	**Grov**	**8**	**114**	**68.8 ± 0.0**	**60.0 ± 2.4**	**1.4e-39**	**1.0**	**(L)**
26	**Grov**	**8**	**144**	**64.9 ± 2.4**	**55.4 ± 1.8**	**1.1e-35**	**1.0**	**(L)**
27	**Grov**	**8**	**174**	**64.1 ± 0.0**	**62.0 ± 2.8**	**2.3e-14**	**0.73**	**(M)**
28	**Grov**	**8**	**204**	**69.2 ± 1.2**	**59.6 ± 2.1**	**9.2e-37**	**1.0**	**(L)**
29	**Grov**	**8**	**234**	**66.4 ± 0.0**	**62.0 ± 5.1**	**1.1e-17**	**0.775**	**(L)**
30	**Grov**	**8**	**264**	**61.7 ± 2.4**	**58.5 ± 1.5**	**6.5e-21**	**0.845**	**(L)**
31	**Grov**	**8**	**294**	**64.5 ± 2.8**	**58.4 ± 2.0**	**2.1e-35**	**1.0**	**(L)**
32	Grov	8	324	57.0 ± 0.0	56.6 ± 1.7	0.89033	0.495	(N)
33	**Grov**	**8**	**354**	**60.9 ± 0.0**	**59.0 ± 2.0**	**8.1e-16**	**0.75**	**(L)**
34	Grov	9	101	87.9 ± 4.3	87.3 ± 3.4	0.10776	0.56	(N)
35	**Grov**	**9**	**166**	**70.4 ± 4.0**	**64.9 ± 2.0**	**5.1e-21**	**0.88**	**(L)**
36	**Grov**	**9**	**144**	**71.1 ± 0.4**	**67.7 ± 2.7**	**5.7e-26**	**0.909**	**(L)**
37	Grov	9	204	68.8 ± 0.0	66.9 ± 3.8	0.1884	0.55	(N)
38	**Grov**	**9**	**264**	**65.5 ± 1.9**	**64.2 ± 3.5**	**0.00829**	**0.601**	**(S)**
39	**Grov**	**9**	**324**	**66.0 ± 0.0**	**59.4 ± 1.9**	**2.6e-39**	**1.0**	**(L)**
40	**Grov**	**9**	**384**	**61.7 ± 1.1**	**57.5 ± 1.3**	**3.9e-36**	**1.0**	**(L)**
41	**Grov**	**9**	**444**	**61.8 ± 1.2**	**60.2 ± 2.7**	**2.5e-05**	**0.659**	**(S)**
42	**Grov**	**9**	**504**	**62.5 ± 1.7**	**58.6 ± 1.3**	**1.6e-35**	**1.0**	**(L)**
43	**Grov**	**9**	**564**	**68.0 ± 0.0**	**62.8 ± 3.0**	**2.0e-39**	**1.0**	**(L)**
44	**Grov**	**9**	**624**	**60.4 ± 1.6**	**59.4 ± 2.1**	**2.1e-07**	**0.708**	**(M)**
45	**Grov**	**9**	**684**	**63.7 ± 0.0**	**58.2 ± 1.6**	**2.3e-39**	**1.0**	**(L)**

Table 2. Reduction rate results for the **Qwalk** program category.

ID	Category	#Qubits	Depth	Greedy [%]	Random [%]	p-value	$\hat{A}_{12}$	Magnitude
0	Qwalk	3	14	50.0 ± 0.0	43.0 ± 17.4	1.1e-04	0.57	(N)
1	**Qwalk**	**3**	**21**	**50.0 ± 0.0**	**34.0 ± 23.4**	**7.5e-10**	**0.66**	**(S)**
2	Qwalk	3	28	0.0 ± 0.0	0.0 ± 0.0	1.0	0.5	(N)
3	Qwalk	3	35	0.0 ± 0.0	0.0 ± 0.0	1.0	0.5	(N)
4	Qwalk	3	42	50.0 ± 0.0	46.5 ± 12.8	0.0073	0.535	(N)
5	**Qwalk**	**3**	**49**	**50.0 ± 0.0**	**30.0 ± 24.6**	**1.8e-12**	**0.7**	**(M)**
6	Qwalk	3	56	0.0 ± 0.0	0.0 ± 0.0	1.0	0.5	(N)
7	Qwalk	3	63	0.0 ± 0.0	0.0 ± 0.0	1.0	0.5	(N)
8	Qwalk	3	70	50.0 ± 0.0	46.5 ± 12.8	0.0073	0.535	(N)
9	**Qwalk**	**3**	**77**	**50.0 ± 0.0**	**31.0 ± 24.4**	**8.5e-12**	**0.69**	**(M)**
10	Qwalk	3	84	0.0 ± 0.0	0.0 ± 0.0	1.0	0.5	(N)
11	Qwalk	3	91	0.0 ± 0.0	0.0 ± 0.0	1.0	0.5	(N)
12	Qwalk	3	98	50.0 ± 0.0	45.5 ± 14.4	0.00222	0.545	(N)
13	Qwalk	4	18	0.0 ± 0.0	0.0 ± 0.0	1.0	0.5	(N)
14	**Qwalk**	**4**	**27**	**20.0 ± 0.0**	**15.8 ± 8.2**	**1.4e-06**	**0.605**	**(S)**
15	Qwalk	4	36	50.0 ± 0.0	49.2 ± 3.0	0.01326	0.53	(N)
16	Qwalk	4	45	20.0 ± 0.0	18.2 ± 5.8	0.00222	0.545	(N)
17	Qwalk	4	54	50.0 ± 0.0	49.6 ± 2.1	0.08274	0.515	(N)
18	Qwalk	4	63	20.0 ± 0.0	18.8 ± 4.8	0.01326	0.53	(N)
19	Qwalk	4	72	50.0 ± 0.0	48.6 ± 3.9	6.7e-04	0.555	(N)
20	Qwalk	4	81	20.0 ± 0.0	17.6 ± 6.5	3.7e-04	0.56	(N)
21	**Qwalk**	**4**	**90**	**50.0 ± 0.0**	**25.5 ± 25.1**	**9.4e-16**	**0.745**	**(L)**
22	**Qwalk**	**4**	**99**	**75.0 ± 0.0**	**71.0 ± 9.2**	**3.2e-05**	**0.58**	**(S)**
23	**Qwalk**	**4**	**108**	**50.0 ± 0.0**	**37.0 ± 22.0**	**5.0e-08**	**0.63**	**(S)**
24	Qwalk	4	117	50.0 ± 0.0	47.5 ± 11.0	0.02417	0.525	(N)
25	Qwalk	4	126	0.0 ± 0.0	0.0 ± 0.0	1.0	0.5	(N)
26	Qwalk	5	22	0.0 ± 0.0	0.0 ± 0.0	1.0	0.5	(N)
27	Qwalk	5	33	0.0 ± 0.0	0.0 ± 0.0	1.0	0.5	(N)
28	Qwalk	5	44	0.0 ± 0.0	0.0 ± 0.0	1.0	0.5	(N)
29	Qwalk	5	55	0.0 ± 0.0	0.0 ± 0.0	1.0	0.5	(N)
30	**Qwalk**	**5**	**66**	**0.0 ± 0.0**	**2.7 ± 3.9**	**7.5e-10**	**0.34**	**(S)**
31	**Qwalk**	**5**	**77**	**30.8 ± 0.0**	**10.3 ± 5.0**	**5.6e-40**	**1.0**	**(L)**
32	**Qwalk**	**5**	**88**	**37.5 ± 0.0**	**32.6 ± 8.7**	**1.0e-07**	**0.625**	**(S)**
33	**Qwalk**	**5**	**99**	**30.8 ± 0.0**	**18.5 ± 13.7**	**1.6e-18**	**0.785**	**(L)**
34	**Qwalk**	**5**	**110**	**50.0 ± 0.0**	**36.6 ± 15.7**	**1.8e-15**	**0.745**	**(L)**
35	**Qwalk**	**5**	**121**	**33.3 ± 0.0**	**27.5 ± 6.7**	**6.9e-14**	**0.72**	**(M)**
36	**Qwalk**	**5**	**132**	**50.0 ± 0.0**	**40.3 ± 10.3**	**3.5e-15**	**0.74**	**(L)**
37	**Qwalk**	**5**	**143**	**0.0 ± 0.0**	**5.7 ± 7.0**	**1.8e-12**	**0.3**	**(M)**
38	**Qwalk**	**5**	**154**	**31.2 ± 0.0**	**26.6 ± 6.0**	**1.0e-16**	**0.76**	**(L)**

Table 3. Reduction rate results for the **Var** program category.

ID	Category	#Qubits	Depth	Greedy [%]	Random [%]	p-value	$\hat{A}_{12}$	Magnitude
0	Var	2	6	25.0 ± 0.0	25.0 ± 0.0	1.0	0.5	(N)
1	Var	2	6	25.0 ± 0.0	25.0 ± 0.0	1.0	0.5	(N)
2	Var	2	7	25.0 ± 0.0	25.0 ± 0.0	1.0	0.5	(N)
3	Var	2	7	25.0 ± 0.0	25.0 ± 0.0	1.0	0.5	(N)
4	**Var**	**3**	**3**	**75.0 ± 0.0**	**69.2 ± 10.6**	**3.7e-07**	**0.615**	**(S)**
5	**Var**	**3**	**4**	**75.0 ± 0.0**	**69.2 ± 10.6**	**3.7e-07**	**0.615**	**(S)**
6	**Var**	**3**	**3**	**75.0 ± 0.0**	**68.0 ± 11.3**	**1.3e-08**	**0.64**	**(S)**
7	**Var**	**3**	**4**	**75.0 ± 0.0**	**70.0 ± 10.1**	**2.6e-06**	**0.6**	**(S)**
8	Var	3	4	68.0 ± 11.3	70.0 ± 10.1	0.18698	0.46	(N)
9	**Var**	**3**	**4**	**64.0 ± 12.5**	**69.5 ± 10.4**	**9.7e-04**	**0.39**	**(S)**
10	Var	3	5	68.5 ± 11.0	67.5 ± 11.5	0.53079	0.52	(N)
11	Var	3	5	66.0 ± 12.1	68.0 ± 11.3	0.227	0.46	(N)
12	**Var**	**4**	**69**	**75.0 ± 0.0**	**63.2 ± 14.0**	**3.1e-14**	**0.725**	**(M)**
13	**Var**	**4**	**70**	**93.8 ± 0.0**	**87.5 ± 0.0**	**3.5e-45**	**1.0**	**(L)**
14	**Var**	**4**	**70**	**93.8 ± 0.0**	**87.5 ± 0.0**	**3.5e-45**	**1.0**	**(L)**
15	**Var**	**4**	**70**	**93.8 ± 0.0**	**87.5 ± 0.0**	**3.5e-45**	**1.0**	**(L)**
16	Var	4	11	66.8 ± 11.8	65.5 ± 12.2	0.46201	0.525	(N)
17	Var	4	11	66.5 ± 11.9	63.5 ± 12.5	0.0843	0.56	(N)
18	Var	4	12	67.0 ± 11.7	64.5 ± 12.4	0.14444	0.55	(N)
19	Var	4	12	65.5 ± 12.2	63.2 ± 12.5	0.19959	0.545	(N)
20	**Var**	**5**	**11**	**50.0 ± 0.0**	**44.1 ± 13.1**	**5.3e-08**	**0.63**	**(S)**
21	**Var**	**5**	**11**	**50.0 ± 0.0**	**44.4 ± 13.1**	**2.0e-07**	**0.62**	**(S)**
22	**Var**	**5**	**12**	**50.0 ± 0.0**	**45.0 ± 13.1**	**5.0e-06**	**0.595**	**(S)**
23	**Var**	**5**	**12**	**50.0 ± 0.0**	**43.1 ± 14.5**	**1.4e-08**	**0.64**	**(S)**
24	Var	6	8	0.0 ± 0.0	0.0 ± 0.0	1.0	0.5	(N)
25	**Var**	**6**	**8**	**50.0 ± 0.0**	**29.0 ± 24.8**	**3.6e-13**	**0.71**	**(M)**
26	Var	6	8	0.0 ± 0.0	0.0 ± 0.0	1.0	0.5	(N)
27	Var	6	8	0.0 ± 0.0	0.0 ± 0.0	1.0	0.5	(N)
28	**Var**	**6**	**14**	**50.0 ± 0.0**	**26.0 ± 25.1**	**2.3e-15**	**0.74**	**(L)**
29	**Var**	**6**	**14**	**50.0 ± 0.0**	**26.0 ± 25.1**	**2.3e-15**	**0.74**	**(L)**
30	**Var**	**6**	**14**	**0.0 ± 0.0**	**9.0 ± 19.3**	**9.3e-06**	**0.41**	**(S)**
31	**Var**	**6**	**14**	**50.0 ± 0.0**	**28.5 ± 24.9**	**1.6e-13**	**0.715**	**(M)**
32	Var	6	11	0.0 ± 0.0	0.0 ± 0.0	1.0	0.5	(N)
33	Var	6	12	0.0 ± 0.0	0.0 ± 0.0	1.0	0.5	(N)
34	Var	6	12	0.0 ± 0.0	0.0 ± 0.0	1.0	0.5	(N)
35	Var	6	12	0.0 ± 0.0	0.0 ± 0.0	1.0	0.5	(N)
36	**Var**	**7**	**41**	**87.5 ± 0.0**	**37.5 ± 21.8**	**1.9e-41**	**1.0**	**(L)**
37	**Var**	**7**	**41**	**37.5 ± 0.0**	**18.8 ± 18.8**	**3.9e-16**	**0.75**	**(L)**
38	**Var**	**7**	**41**	**37.5 ± 0.0**	**19.5 ± 18.8**	**2.3e-15**	**0.74**	**(L)**
39	**Var**	**7**	**41**	**87.5 ± 0.0**	**36.0 ± 22.6**	**3.3e-41**	**1.0**	**(L)**
40	**Var**	**8**	**17**	**63.0 ± 12.6**	**50.2 ± 21.5**	**5.3e-06**	**0.664**	**(S)**
41	**Var**	**8**	**17**	**64.0 ± 12.5**	**53.5 ± 20.4**	**1.1e-04**	**0.64**	**(S)**
42	**Var**	**8**	**17**	**62.2 ± 12.6**	**52.2 ± 20.7**	**4.6e-04**	**0.626**	**(S)**
43	**Var**	**8**	**17**	**65.0 ± 12.3**	**53.2 ± 21.2**	**1.9e-05**	**0.655**	**(S)**

Table 4. Reduction rate results for the **Gs** program category.

ID	Category	#Qubits	Depth	Greedy [%]	Random [%]	p-value	$\hat{A}_{12}$	Magnitude
0	**Gs**	**3**	**5**	**50.0 ± 0.0**	**29.5 ± 24.7**	**8.0e-13**	**0.705**	**(M)**
1	**Gs**	**4**	**6**	**50.0 ± 0.0**	**35.5 ± 22.8**	**6.3e-09**	**0.645**	**(S)**
2	**Gs**	**5**	**7**	**67.8 ± 11.4**	**59.5 ± 16.2**	**7.7e-05**	**0.639**	**(S)**
3	**Gs**	**6**	**8**	**75.0 ± 0.0**	**68.2 ± 11.2**	**2.5e-08**	**0.635**	**(S)**
4	Gs	7	9	80.2 ± 6.2	80.0 ± 6.9	0.9353	0.503	(N)
5	**Gs**	**8**	**10**	**86.0 ± 4.1**	**79.4 ± 6.7**	**1.0e-13**	**0.756**	**(L)**
6	**Gs**	**9**	**11**	**89.6 ± 3.0**	**83.9 ± 5.7**	**3.9e-15**	**0.762**	**(L)**
7	**Gs**	**10**	**12**	**92.3 ± 2.6**	**85.4 ± 4.7**	**1.3e-28**	**0.905**	**(L)**
8	**Gs**	**11**	**13**	**94.2 ± 1.9**	**85.4 ± 4.7**	**8.5e-37**	**0.983**	**(L)**
9	**Gs**	**12**	**14**	**95.8 ± 1.5**	**86.1 ± 3.9**	**3.3e-39**	**1.0**	**(L)**
10	**Gs**	**13**	**15**	**96.8 ± 1.2**	**87.5 ± 0.0**	**4.2e-41**	**1.0**	**(L)**
11	**Gs**	**14**	**16**	**97.6 ± 0.9**	**90.3 ± 3.1**	**3.3e-36**	**0.998**	**(L)**
12	**Gs**	**15**	**17**	**98.2 ± 0.7**	**89.9 ± 3.1**	**3.3e-37**	**1.0**	**(L)**
13	**Gs**	**16**	**18**	**98.7 ± 0.6**	**90.1 ± 3.1**	**1.8e-36**	**1.0**	**(L)**

approach where $\hat{A}_{12}$ is the Vargha-Delanay effect size along with its nominal effect size magnitude category. If a result is significant, rows are made bold. In the runtime tables, we also include two extra columns. The **#T** column, shows the number of objective function evaluations used experimentally by the Greedy approach. Next, the **f(#Qubits)** column shows the theoretical maximum number of objective function calls given by Eq. (6) with $\#Qubits = n$.

5.2 RQ2 Tables

In Tables 9 to 12, we depict the testing runtimes for RQ2 by program category and qubit count. The gray columns **Default**, **Greedy** and **Random** show the testing runtimes in seconds for the respective approach. In the **DGR** column, we show the p-value resulting from a Kruskal-Wallis test between the three approaches where **D** refers to Default, **G** to Greedy and **R** to Random. Following this, in the **DG**, **DR** and **GR** columns, we show the pairwise statistical test results, consisting of the p-value, effect size and effect magnitude category for the comparisons between the respective approaches.

5.3 RQ3 Tables

In Tables 13 to 21, we show the mutation score results for RQ3 by mutant, category, and qubit count. In the gray columns **Default**, **Greedy** and **Random**, we list the mutation scores and to the right of the gray columns we provide the statistical test results as we described for the RQ2 tables.

Table 5. Reduction runtime results for the Grov program category.

ID	Category	#Qubits	Depth	#T	f(#Q)	Greedy [ms]	Random [ms]	p-value	$\hat{A}_{12}$	Magnitude
0	Grov	6	178	18	21	313.2 ± 25.7	313.2 ± 25.0	0.91342	0.505	(N)
1	**Grov**	**6**	**30**	**15**	**21**	**99.9 ± 5.0**	**103.4 ± 5.1**	**2.3e-26**	**0.065**	**(L)**
2	**Grov**	**6**	**121**	**15**	**21**	**196.2 ± 13.8**	**200.2 ± 13.8**	**1.3e-23**	**0.09**	**(L)**
3	**Grov**	**6**	**42**	**18**	**21**	**122.3 ± 7.4**	**124.0 ± 6.9**	**1.7e-05**	**0.324**	**(M)**
4	**Grov**	**6**	**48**	**18**	**21**	**120.5 ± 11.5**	**121.2 ± 8.0**	**0.00112**	**0.367**	**(S)**
5	**Grov**	**6**	**54**	**18**	**21**	**119.8 ± 8.7**	**122.3 ± 7.9**	**4.5e-06**	**0.312**	**(M)**
6	**Grov**	**6**	**66**	**15**	**21**	**128.3 ± 7.4**	**132.2 ± 7.5**	**5.7e-26**	**0.069**	**(L)**
7	Grov	6	72	18	21	141.4 ± 7.8	141.5 ± 7.7	0.27636	0.455	(N)
8	**Grov**	**6**	**78**	**15**	**21**	**126.6 ± 7.8**	**129.3 ± 7.0**	**7.4e-22**	**0.107**	**(L)**
9	**Grov**	**6**	**125**	**21**	**21**	**198.6 ± 11.4**	**195.3 ± 11.6**	**5.7e-22**	**0.894**	**(L)**
10	**Grov**	**6**	**90**	**18**	**21**	**150.6 ± 9.7**	**152.2 ± 9.2**	**5.0e-07**	**0.294**	**(M)**
11	**Grov**	**7**	**57**	**22**	**28**	**195.6 ± 15.1**	**201.1 ± 14.0**	**3.5e-07**	**0.291**	**(M)**
12	**Grov**	**7**	**36**	**22**	**28**	**135.5 ± 10.3**	**141.0 ± 8.7**	**7.1e-13**	**0.206**	**(L)**
13	**Grov**	**7**	**48**	**25**	**28**	**167.9 ± 10.3**	**169.7 ± 9.7**	**0.02627**	**0.409**	**(S)**
14	**Grov**	**7**	**205**	**22**	**28**	**325.1 ± 25.6**	**330.4 ± 24.7**	**1.5e-06**	**0.303**	**(M)**
15	**Grov**	**7**	**492**	**18**	**28**	**614.4 ± 54.8**	**618.1 ± 52.2**	**1.0e-05**	**0.319**	**(M)**
16	**Grov**	**7**	**96**	**18**	**28**	**186.7 ± 12.1**	**191.7 ± 11.6**	**8.4e-25**	**0.079**	**(L)**
17	**Grov**	**7**	**108**	**22**	**28**	**201.7 ± 10.8**	**204.2 ± 11.2**	**3.4e-09**	**0.258**	**(L)**
18	**Grov**	**7**	**120**	**25**	**28**	**247.0 ± 14.2**	**247.4 ± 13.8**	**0.02939**	**0.411**	**(S)**
19	**Grov**	**7**	**132**	**25**	**28**	**234.8 ± 16.7**	**237.3 ± 16.0**	**2.3e-04**	**0.349**	**(S)**
20	**Grov**	**7**	**144**	**25**	**28**	**243.1 ± 16.2**	**246.1 ± 15.5**	**3.6e-07**	**0.292**	**(M)**
21	**Grov**	**7**	**156**	**22**	**28**	**216.6 ± 17.3**	**220.4 ± 17.9**	**6.6e-05**	**0.337**	**(S)**
22	**Grov**	**8**	**79**	**30**	**36**	**299.5 ± 20.8**	**305.7 ± 19.7**	**4.6e-06**	**0.312**	**(M)**
23	**Grov**	**8**	**54**	**30**	**36**	**221.7 ± 16.8**	**227.0 ± 14.9**	**1.1e-05**	**0.32**	**(M)**
24	**Grov**	**8**	**84**	**26**	**36**	**230.1 ± 13.2**	**236.9 ± 11.7**	**1.6e-15**	**0.174**	**(L)**
25	**Grov**	**8**	**114**	**30**	**36**	**290.6 ± 14.6**	**293.5 ± 14.9**	**3.5e-08**	**0.274**	**(M)**
26	**Grov**	**8**	**144**	**30**	**36**	**297.0 ± 20.1**	**304.3 ± 18.1**	**3.2e-07**	**0.291**	**(M)**
27	Grov	8	174	30	36	392.9 ± 140.8	332.5 ± 18.5	0.0676	0.575	(S)
28	**Grov**	**8**	**204**	**30**	**36**	**393.8 ± 38.9**	**382.7 ± 26.0**	**0.02047**	**0.595**	**(S)**
29	**Grov**	**8**	**234**	**26**	**36**	**384.4 ± 28.4**	**386.1 ± 26.4**	**3.7e-04**	**0.354**	**(S)**
30	**Grov**	**8**	**264**	**26**	**36**	**412.1 ± 35.8**	**400.0 ± 27.0**	**1.2e-06**	**0.699**	**(M)**
31	**Grov**	**8**	**294**	**26**	**36**	**441.5 ± 33.8**	**424.8 ± 28.0**	**1.3e-12**	**0.791**	**(L)**
32	Grov	8	324	26	36	473.6 ± 36.1	470.0 ± 33.8	0.9076	0.505	(N)
33	**Grov**	**8**	**354**	**30**	**36**	**752.4 ± 330.7**	**519.0 ± 37.0**	**5.8e-05**	**0.665**	**(S)**
34	**Grov**	**9**	**101**	**35**	**45**	**458.8 ± 35.7**	**433.9 ± 27.0**	**6.8e-12**	**0.781**	**(L)**
35	Grov	9	166	35	45	596.2 ± 423.5	437.5 ± 29.2	0.97856	0.501	(N)
36	**Grov**	**9**	**144**	**30**	**45**	**392.6 ± 21.9**	**397.7 ± 20.5**	**6.0e-09**	**0.262**	**(L)**
37	**Grov**	**9**	**204**	**30**	**45**	**575.7 ± 432.9**	**448.0 ± 24.5**	**0.01041**	**0.605**	**(S)**
38	**Grov**	**9**	**264**	**35**	**45**	**607.7 ± 228.1**	**546.5 ± 37.1**	**3.1e-07**	**0.71**	**(M)**
39	Grov	9	324	30	45	585.7 ± 40.7	580.8 ± 36.4	0.45835	0.47	(N)
40	**Grov**	**9**	**384**	**35**	**45**	**664.1 ± 54.2**	**645.6 ± 42.4**	**1.1e-04**	**0.658**	**(S)**
41	**Grov**	**9**	**444**	**30**	**45**	**712.9 ± 51.0**	**716.6 ± 50.6**	**2.1e-16**	**0.164**	**(L)**
42	Grov	9	504	39	45	808.3 ± 64.8	809.3 ± 62.2	0.66628	0.482	(N)
43	Grov	9	564	35	45	859.4 ± 73.0	848.2 ± 58.8	0.06454	0.424	(S)
44	**Grov**	**9**	**624**	**35**	**45**	**913.3 ± 68.7**	**916.5 ± 69.2**	**0.03907**	**0.416**	**(S)**
45	**Grov**	**9**	**684**	**30**	**45**	**946.6 ± 73.5**	**949.7 ± 71.8**	**3.4e-06**	**0.31**	**(M)**

Table 6. Reduction runtime results for the **Qwalk** program category.

ID	Category	#Qubits	Depth	#T	f(#Q)	Greedy [ms]	Random [ms]	p-value	$\hat{A}_{12}$	Magnitude
0	**Qwalk**	**3**	**14**	**5**	**6**	**31.4 ± 3.8**	**31.7 ± 1.8**	**1.6e-09**	**0.253**	**(L)**
1	**Qwalk**	**3**	**21**	**5**	**6**	**34.7 ± 2.3**	**35.2 ± 1.3**	**4.5e-13**	**0.204**	**(L)**
2	**Qwalk**	**3**	**28**	**3**	**6**	**31.4 ± 3.4**	**32.8 ± 1.7**	**2.6e-28**	**0.048**	**(L)**
3	**Qwalk**	**3**	**35**	**3**	**6**	**34.4 ± 2.4**	**36.5 ± 2.7**	**2.0e-31**	**0.023**	**(L)**
4	**Qwalk**	**3**	**42**	**5**	**6**	**44.5 ± 2.9**	**45.2 ± 2.2**	**1.9e-14**	**0.186**	**(L)**
5	**Qwalk**	**3**	**49**	**5**	**6**	**48.1 ± 2.4**	**48.4 ± 3.1**	**0.01445**	**0.4**	**(S)**
6	**Qwalk**	**3**	**56**	**3**	**6**	**44.7 ± 3.9**	**46.8 ± 8.3**	**7.4e-25**	**0.079**	**(L)**
7	**Qwalk**	**3**	**63**	**3**	**6**	**48.6 ± 3.9**	**49.4 ± 4.6**	**3.3e-12**	**0.215**	**(L)**
8	**Qwalk**	**3**	**70**	**5**	**6**	**58.6 ± 4.1**	**58.8 ± 4.0**	**5.7e-05**	**0.335**	**(S)**
9	**Qwalk**	**3**	**77**	**5**	**6**	**61.6 ± 4.2**	**62.3 ± 4.4**	**3.9e-10**	**0.244**	**(L)**
10	**Qwalk**	**3**	**84**	**3**	**6**	**58.3 ± 4.4**	**59.2 ± 5.1**	**8.3e-13**	**0.207**	**(L)**
11	**Qwalk**	**3**	**91**	**3**	**6**	**61.2 ± 4.6**	**62.5 ± 4.7**	**1.4e-21**	**0.109**	**(L)**
12	**Qwalk**	**3**	**98**	**5**	**6**	**71.2 ± 5.1**	**71.5 ± 4.8**	**7.1e-04**	**0.361**	**(S)**
13	**Qwalk**	**4**	**18**	**4**	**10**	**31.2 ± 2.0**	**33.5 ± 2.1**	**2.3e-29**	**0.04**	**(L)**
14	**Qwalk**	**4**	**27**	**7**	**10**	**46.3 ± 2.6**	**48.2 ± 2.9**	**1.8e-25**	**0.073**	**(L)**
15	Qwalk	4	36	9	10	58.7 ± 2.7	58.7 ± 2.8	0.12048	0.564	(N)
16	**Qwalk**	**4**	**45**	**7**	**10**	**56.3 ± 4.5**	**57.0 ± 3.4**	**1.7e-11**	**0.225**	**(L)**
17	**Qwalk**	**4**	**54**	**9**	**10**	**69.2 ± 4.5**	**69.8 ± 12.2**	**1.3e-05**	**0.678**	**(M)**
18	**Qwalk**	**4**	**63**	**7**	**10**	**65.8 ± 4.0**	**67.1 ± 4.1**	**6.4e-13**	**0.206**	**(L)**
19	**Qwalk**	**4**	**72**	**9**	**10**	**78.7 ± 4.7**	**78.4 ± 4.6**	**0.0182**	**0.597**	**(S)**
20	**Qwalk**	**4**	**81**	**7**	**10**	**76.0 ± 5.0**	**76.8 ± 4.8**	**2.0e-06**	**0.305**	**(M)**
21	Qwalk	4	90	7	10	82.1 ± 6.0	81.9 ± 5.7	0.34187	0.461	(N)
22	**Qwalk**	**4**	**99**	**9**	**10**	**93.9 ± 7.9**	**93.4 ± 6.0**	**0.04472**	**0.418**	**(S)**
23	**Qwalk**	**4**	**108**	**7**	**10**	**90.7 ± 6.3**	**92.0 ± 6.5**	**6.7e-14**	**0.193**	**(L)**
24	**Qwalk**	**4**	**117**	**7**	**10**	**95.7 ± 6.8**	**97.1 ± 6.9**	**8.2e-14**	**0.194**	**(L)**
25	**Qwalk**	**4**	**126**	**4**	**10**	**91.2 ± 7.6**	**92.5 ± 7.3**	**2.1e-20**	**0.121**	**(L)**
26	**Qwalk**	**5**	**22**	**5**	**15**	**38.4 ± 4.8**	**41.0 ± 1.7**	**1.1e-31**	**0.021**	**(L)**
27	**Qwalk**	**5**	**33**	**5**	**15**	**44.9 ± 2.8**	**48.1 ± 4.1**	**1.3e-30**	**0.029**	**(L)**
28	**Qwalk**	**5**	**44**	**5**	**15**	**52.1 ± 4.2**	**54.4 ± 3.3**	**4.3e-28**	**0.05**	**(L)**
29	**Qwalk**	**5**	**55**	**5**	**15**	**59.4 ± 6.1**	**61.1 ± 4.3**	**2.0e-26**	**0.065**	**(L)**
30	**Qwalk**	**5**	**66**	**5**	**15**	**65.2 ± 4.3**	**67.7 ± 4.5**	**1.8e-26**	**0.064**	**(L)**
31	**Qwalk**	**5**	**77**	**12**	**15**	**95.7 ± 6.5**	**97.5 ± 5.6**	**1.8e-18**	**0.141**	**(L)**
32	**Qwalk**	**5**	**88**	**12**	**15**	**102.2 ± 5.6**	**104.1 ± 5.7**	**9.0e-20**	**0.128**	**(L)**
33	**Qwalk**	**5**	**99**	**12**	**15**	**109.0 ± 6.5**	**110.4 ± 6.7**	**6.4e-16**	**0.169**	**(L)**
34	**Qwalk**	**5**	**110**	**12**	**15**	**115.4 ± 7.4**	**117.0 ± 7.2**	**7.8e-17**	**0.159**	**(L)**
35	**Qwalk**	**5**	**121**	**14**	**15**	**130.8 ± 8.3**	**129.8 ± 7.3**	**4.4e-06**	**0.688**	**(M)**
36	**Qwalk**	**5**	**132**	**12**	**15**	**128.1 ± 8.1**	**130.3 ± 9.9**	**2.1e-16**	**0.164**	**(L)**
37	**Qwalk**	**5**	**143**	**5**	**15**	**110.7 ± 9.8**	**113.3 ± 8.7**	**7.0e-26**	**0.069**	**(L)**
38	**Qwalk**	**5**	**154**	**12**	**15**	**142.8 ± 13.2**	**142.5 ± 9.5**	**2.8e-06**	**0.308**	**(M)**

Table 7. Reduction runtime results for the **Var** program category.

ID	Category	#Qubits	Depth	#T	f(#Q)	Greedy [ms]	Random [ms]	p-value	$\hat{A}_{12}$	Magnitude
0	**Var**	**2**	**6**	**3**	**3**	**24.4 ± 33.2**	**22.8 ± 25.5**	**7.1e-27**	**0.939**	**(L)**
1	**Var**	**2**	**6**	**3**	**3**	**21.8 ± 4.0**	**20.7 ± 2.8**	**1.1e-25**	**0.929**	**(L)**
2	**Var**	**2**	**7**	**3**	**3**	**21.3 ± 4.4**	**20.4 ± 0.6**	**2.3e-15**	**0.824**	**(L)**
3	**Var**	**2**	**7**	**3**	**3**	**21.4 ± 0.6**	**20.7 ± 3.5**	**9.4e-28**	**0.947**	**(L)**
4	**Var**	**3**	**3**	**6**	**6**	**28.9 ± 2.7**	**28.1 ± 0.8**	**3.1e-09**	**0.743**	**(L)**
5	**Var**	**3**	**4**	**6**	**6**	**29.8 ± 1.3**	**29.3 ± 1.0**	**0.00555**	**0.614**	**(S)**
6	**Var**	**3**	**3**	**6**	**6**	**30.2 ± 5.4**	**29.4 ± 2.8**	**4.2e-07**	**0.707**	**(M)**
7	**Var**	**3**	**4**	**6**	**6**	**29.7 ± 3.1**	**29.0 ± 0.8**	**3.1e-07**	**0.71**	**(M)**
8	Var	3	4	6	6	27.7 ± 1.9	28.1 ± 3.1	0.76936	0.488	(N)
9	Var	3	4	6	6	29.0 ± 4.1	28.9 ± 1.7	0.22978	0.451	(N)
10	**Var**	**3**	**5**	**6**	**6**	**29.5 ± 1.9**	**29.3 ± 1.4**	**0.00936**	**0.606**	**(S)**
11	**Var**	**3**	**5**	**6**	**6**	**29.5 ± 3.2**	**29.1 ± 3.2**	**0.00209**	**0.626**	**(S)**
12	Var	4	69	9	10	87.8 ± 5.3	88.0 ± 5.8	0.90664	0.495	(N)
13	**Var**	**4**	**70**	**10**	**10**	**93.0 ± 5.9**	**91.7 ± 5.1**	**2.3e-14**	**0.812**	**(L)**
14	**Var**	**4**	**70**	**10**	**10**	**93.1 ± 5.7**	**91.8 ± 5.6**	**7.1e-13**	**0.794**	**(L)**
15	**Var**	**4**	**70**	**10**	**10**	**93.0 ± 5.1**	**92.0 ± 5.6**	**2.2e-16**	**0.836**	**(L)**
16	Var	4	11	9	10	44.4 ± 4.6	44.2 ± 3.5	0.1949	0.553	(N)
17	Var	4	11	9	10	44.3 ± 4.0	44.3 ± 3.2	0.869	0.507	(N)
18	Var	4	12	9	10	44.2 ± 4.1	44.5 ± 3.6	0.61044	0.521	(N)
19	Var	4	12	9	10	44.0 ± 4.5	44.4 ± 3.9	0.435	0.468	(N)
20	**Var**	**5**	**11**	**9**	**15**	**43.8 ± 2.6**	**46.5 ± 2.9**	**1.9e-30**	**0.031**	**(L)**
21	**Var**	**5**	**11**	**9**	**15**	**43.9 ± 1.7**	**47.0 ± 2.1**	**2.3e-31**	**0.023**	**(L)**
22	**Var**	**5**	**12**	**9**	**15**	**43.9 ± 0.7**	**47.1 ± 2.2**	**7.4e-32**	**0.019**	**(L)**
23	**Var**	**5**	**12**	**9**	**15**	**44.0 ± 1.9**	**46.8 ± 2.2**	**8.9e-31**	**0.028**	**(L)**
24	**Var**	**6**	**8**	**6**	**21**	**32.6 ± 2.6**	**36.0 ± 2.1**	**1.5e-31**	**0.022**	**(L)**
25	**Var**	**6**	**8**	**11**	**21**	**49.7 ± 2.9**	**53.9 ± 3.3**	**1.3e-29**	**0.037**	**(L)**
26	**Var**	**6**	**8**	**6**	**21**	**33.2 ± 2.8**	**37.3 ± 1.8**	**6.0e-32**	**0.019**	**(L)**
27	**Var**	**6**	**8**	**6**	**21**	**32.7 ± 1.8**	**36.9 ± 2.7**	**4.9e-31**	**0.026**	**(L)**
28	**Var**	**6**	**14**	**11**	**21**	**50.3 ± 3.6**	**54.7 ± 3.0**	**6.6e-30**	**0.035**	**(L)**
29	**Var**	**6**	**14**	**11**	**21**	**49.6 ± 2.7**	**54.3 ± 2.5**	**1.8e-30**	**0.03**	**(L)**
30	**Var**	**6**	**14**	**6**	**21**	**33.3 ± 2.3**	**37.5 ± 2.2**	**1.8e-29**	**0.039**	**(L)**
31	**Var**	**6**	**14**	**11**	**21**	**50.9 ± 3.9**	**55.3 ± 3.3**	**2.5e-27**	**0.057**	**(L)**
32	**Var**	**6**	**11**	**6**	**21**	**34.0 ± 1.6**	**38.0 ± 1.9**	**1.0e-31**	**0.02**	**(L)**
33	**Var**	**6**	**12**	**6**	**21**	**34.6 ± 2.5**	**39.2 ± 3.2**	**1.3e-30**	**0.029**	**(L)**
34	**Var**	**6**	**12**	**6**	**21**	**33.9 ± 4.5**	**37.7 ± 2.2**	**2.0e-30**	**0.031**	**(L)**
35	**Var**	**6**	**12**	**6**	**21**	**34.1 ± 1.7**	**38.5 ± 2.6**	**8.3e-32**	**0.02**	**(L)**
36	**Var**	**7**	**41**	**22**	**28**	**127.2 ± 5.2**	**129.5 ± 5.8**	**2.3e-12**	**0.213**	**(L)**
37	**Var**	**7**	**41**	**13**	**28**	**87.6 ± 8.3**	**93.7 ± 5.6**	**3.4e-26**	**0.067**	**(L)**
38	**Var**	**7**	**41**	**13**	**28**	**86.3 ± 5.0**	**93.7 ± 5.0**	**2.4e-27**	**0.057**	**(L)**
39	**Var**	**7**	**41**	**22**	**28**	**128.6 ± 5.8**	**131.6 ± 6.9**	**2.2e-18**	**0.142**	**(L)**
40	**Var**	**8**	**17**	**21**	**36**	**106.1 ± 16.8**	**116.2 ± 15.6**	**3.3e-07**	**0.291**	**(M)**
41	**Var**	**8**	**17**	**21**	**36**	**107.4 ± 16.6**	**117.4 ± 16.0**	**7.3e-07**	**0.297**	**(M)**
42	**Var**	**8**	**17**	**21**	**36**	**105.8 ± 16.5**	**115.6 ± 15.5**	**2.7e-07**	**0.289**	**(M)**
43	**Var**	**8**	**17**	**21**	**36**	**108.4 ± 16.0**	**118.3 ± 16.7**	**8.8e-08**	**0.281**	**(M)**

Table 8. Reduction runtime results for the **Gs** program category.

ID	Category	#Qubits	Depth	#T	f(#Q)	Greedy [ms]	Random [ms]	p-value	$\hat{A}_{12}$	Magnitude
0	**Gs**	**3**	**5**	**5**	**6**	**24.3 ± 0.4**	**24.9 ± 1.3**	**1.6e-10**	**0.238**	**(L)**
1	**Gs**	**4**	**6**	**7**	**10**	**31.8 ± 1.8**	**33.7 ± 2.1**	**2.7e-29**	**0.04**	**(L)**
2	**Gs**	**5**	**7**	**12**	**15**	**47.6 ± 5.6**	**50.7 ± 5.1**	**7.0e-11**	**0.233**	**(L)**
3	**Gs**	**6**	**8**	**15**	**21**	**65.0 ± 2.1**	**69.3 ± 2.7**	**4.4e-31**	**0.025**	**(L)**
4	**Gs**	**7**	**9**	**22**	**28**	**92.7 ± 10.0**	**99.1 ± 10.4**	**5.3e-08**	**0.277**	**(M)**
5	**Gs**	**8**	**10**	**26**	**36**	**136.8 ± 9.3**	**146.1 ± 9.7**	**2.8e-17**	**0.154**	**(L)**
6	**Gs**	**9**	**11**	**35**	**45**	**222.8 ± 20.8**	**230.3 ± 18.8**	**2.9e-04**	**0.352**	**(S)**
7	**Gs**	**10**	**12**	**40**	**55**	**395.7 ± 28.9**	**401.4 ± 26.5**	**1.2e-07**	**0.284**	**(M)**
8	**Gs**	**11**	**13**	**51**	**66**	**796.9 ± 57.4**	**801.7 ± 52.7**	**8.3e-04**	**0.363**	**(S)**
9	Gs	12	14	57	78	1639.0 ± 106.3	1635.7 ± 97.5	0.12765	0.562	(N)
10	**Gs**	**13**	**15**	**70**	**91**	**3518.0 ± 224.3**	**3493.0 ± 207.7**	**3.4e-04**	**0.647**	**(S)**
11	Gs	14	16	77	105	7885.3 ± 444.1	8607.6 ± 2720.7	0.56501	0.524	(N)
12	**Gs**	**15**	**17**	**92**	**120**	**18830.9 ± 1045.9**	**20129.6 ± 2030.9**	**8.6e-08**	**0.281**	**(M)**
13	**Gs**	**16**	**18**	**100**	**136**	**44088.0 ± 2596.7**	**44240.6 ± 2457.6**	**0.00637**	**0.388**	**(S)**

Table 9. Testing runtime results for the **Grov** program category.

							DGR	DG			DR			GR		
ID	Category	#Qubits	Depth	Default [s]	Greedy [s]	Random [s]	p-value	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude
0	Grov	6	178	77.6 ± 17.8	5.2 ± 7.2	14.8 ± 16.0	1.9e-170	4.2e-124	0.956	(L)	4.7e-124	0.956	(L)	1.0	0.33	(M)
1	Grov	6	30	12.9 ± 2.3	1.7 ± 2.0	1.7 ± 2.0	7.2e-176	9.0e-134	0.973	(L)	8.7e-134	0.973	(L)	0.83744	0.481	(N)
2	Grov	6	121	44.5 ± 8.0	4.1 ± 5.9	4.3 ± 5.8	1.1e-177	4.8e-135	0.976	(L)	4.8e-135	0.976	(L)	0.93558	0.471	(N)
3	Grov	6	42	16.8 ± 3.2	4.0 ± 2.9	2.1 ± 2.7	6.3e-182	3.0e-136	0.978	(L)	2.5e-136	0.978	(L)	3.1e-08	0.604	(S)
4	Grov	6	48	16.9 ± 3.9	2.7 ± 3.5	2.6 ± 3.4	1.3e-164	2.8e-125	0.958	(L)	2.8e-125	0.958	(L)	0.11332	0.523	(N)
5	Grov	6	54	17.5 ± 3.5	3.3 ± 3.8	3.2 ± 3.8	1.1e-169	6.2e-129	0.964	(L)	5.8e-129	0.964	(L)	0.02287	0.538	(N)
6	Grov	6	66	21.8 ± 4.7	2.7 ± 3.8	2.6 ± 3.7	5.6e-168	6.6e-128	0.963	(L)	8.9e-128	0.962	(L)	0.13709	0.521	(N)
7	Grov	6	72	22.2 ± 4.9	1.8 ± 2.5	2.4 ± 3.2	1.1e-170	5.5e-129	0.964	(L)	6.9e-129	0.964	(L)	0.99993	0.427	(N)
8	Grov	6	78	21.8 ± 4.6	2.8 ± 3.5	2.7 ± 3.7	5.1e-173	1.1e-131	0.97	(L)	1.2e-131	0.97	(L)	0.21497	0.515	(N)
9	Grov	6	125	35.3 ± 5.8	0.7 ± 0.5	1.3 ± 1.0	6.7e-181	1.3e-136	0.978	(L)	1.8e-136	0.978	(L)	0.99998	0.422	(S)
10	Grov	6	90	25.5 ± 5.6	6.1 ± 4.3	6.0 ± 4.2	2.9e-169	7.4e-129	0.964	(L)	7.5e-129	0.964	(L)	0.68266	0.491	(N)
11	Grov	7	57	69.8 ± 12.3	3.8 ± 5.2	10.3 ± 11.8	3.3e-183	3.8e-135	0.976	(L)	5.6e-135	0.976	(L)	1.0	0.352	(S)
12	Grov	7	36	35.2 ± 6.8	3.7 ± 5.3	3.8 ± 5.4	2.2e-174	1.6e-132	0.971	(L)	1.6e-132	0.971	(L)	0.95366	0.468	(N)
13	Grov	7	48	41.5 ± 7.5	2.9 ± 4.1	2.9 ± 4.0	1.6e-177	5.0e-135	0.976	(L)	5.3e-135	0.976	(L)	0.15817	0.519	(N)
14	Grov	7	205	155.0 ± 27.9	17.6 ± 26.5	18.3 ± 28.0	6.0e-177	8.0e-134	0.973	(L)	9.8e-134	0.973	(L)	0.99975	0.433	(N)
15	Grov	7	492	340.7 ± 73.0	33.6 ± 53.8	39.5 ± 58.8	4.8e-166	2.0e-126	0.96	(L)	2.0e-126	0.96	(L)	0.69569	0.49	(N)
16	Grov	7	96	67.1 ± 15.1	7.4 ± 11.6	7.7 ± 12.0	6.6e-163	4.6e-124	0.956	(L)	4.8e-124	0.956	(L)	0.77371	0.486	(N)
17	Grov	7	108	66.5 ± 11.5	5.1 ± 7.9	7.4 ± 11.2	1.9e-178	5.3e-135	0.976	(L)	5.6e-135	0.976	(L)	0.99951	0.437	(N)
18	Grov	7	120	86.4 ± 15.4	8.2 ± 11.9	11.4 ± 17.1	2.7e-176	8.8e-134	0.973	(L)	9.6e-134	0.973	(L)	0.99077	0.455	(N)
19	Grov	7	132	82.8 ± 20.0	8.3 ± 13.0	9.4 ± 15.5	3.7e-158	1.6e-120	0.949	(L)	1.5e-120	0.949	(L)	0.58905	0.496	(N)
20	Grov	7	144	91.8 ± 15.2	9.0 ± 13.8	12.0 ± 17.8	4.8e-180	2.9e-136	0.978	(L)	3.2e-136	0.978	(L)	0.99927	0.439	(N)
21	Grov	7	156	81.4 ± 16.3	9.1 ± 14.3	10.6 ± 15.5	4.6e-171	4.4e-130	0.967	(L)	4.6e-130	0.967	(L)	0.92731	0.472	(N)
22	Grov	8	79	200.6 ± 38.2	12.4 ± 20.0	14.0 ± 20.5	6.6e-173	2.6e-131	0.969	(L)	2.7e-131	0.969	(L)	0.98047	0.46	(N)
23	Grov	8	54	97.6 ± 18.8	7.3 ± 12.2	7.3 ± 12.4	1.4e-172	2.7e-131	0.969	(L)	2.8e-131	0.969	(L)	0.83588	0.481	(N)
24	Grov	8	84	124.1 ± 18.8	11.0 ± 18.9	11.9 ± 19.9	2.2e-182	1.0e-138	0.982	(L)	1.0e-138	0.982	(L)	0.62297	0.494	(N)
25	Grov	8	114	171.2 ± 29.5	13.6 ± 22.7	16.5 ± 27.8	2.1e-177	5.7e-135	0.976	(L)	5.5e-135	0.976	(L)	0.45543	0.502	(N)
26	Grov	8	144	192.9 ± 39.1	18.8 ± 28.7	25.0 ± 37.7	2.7e-171	3.6e-129	0.965	(L)	4.6e-129	0.965	(L)	0.99999	0.419	(S)
27	Grov	8	174	218.0 ± 39.5	20.8 ± 33.7	20.8 ± 33.8	2.0e-174	1.7e-132	0.971	(L)	1.7e-132	0.971	(L)	0.03615	0.535	(N)
28	Grov	8	204	297.1 ± 52.0	23.8 ± 38.4	32.7 ± 52.0	3.3e-176	9.6e-134	0.973	(L)	9.7e-134	0.973	(L)	0.98504	0.458	(N)
29	Grov	8	234	316.8 ± 51.2	27.0 ± 45.2	30.5 ± 50.3	4.0e-179	3.2e-136	0.978	(L)	3.2e-136	0.978	(L)	0.79822	0.484	(N)
30	Grov	8	264	338.2 ± 50.7	35.0 ± 58.1	32.6 ± 54.8	1.6e-182	1.0e-138	0.982	(L)	1.0e-138	0.982	(L)	0.11062	0.524	(N)
31	Grov	8	294	372.8 ± 46.6	40.3 ± 60.3	39.1 ± 64.4	1.8e-187	1.6e-142	0.989	(L)	1.6e-142	0.989	(L)	0.27613	0.511	(N)
32	Grov	8	324	428.7 ± 67.1	49.6 ± 79.3	49.4 ± 78.1	7.6e-181	1.8e-137	0.98	(L)	1.8e-137	0.98	(L)	0.11948	0.523	(N)
33	Grov	8	354	462.1 ± 88.2	43.7 ± 75.1	46.5 ± 80.4	1.8e-172	2.8e-131	0.969	(L)	2.8e-131	0.969	(L)	0.60036	0.495	(N)
34	Grov	9	101	521.0 ± 97.1	15.8 ± 21.4	20.7 ± 31.6	3.7e-174	1.6e-132	0.971	(L)	1.6e-132	0.971	(L)	0.27209	0.512	(N)
35	Grov	9	166	570.6 ± 101.0	37.4 ± 67.6	47.7 ± 85.2	4.1e-179	3.2e-136	0.978	(L)	3.2e-136	0.978	(L)	0.79871	0.484	(N)
36	Grov	9	144	498.5 ± 88.5	36.7 ± 62.2	38.7 ± 66.7	4.3e-179	3.2e-136	0.978	(L)	3.3e-136	0.978	(L)	0.76164	0.486	(N)
37	Grov	9	204	617.6 ± 121.6	49.0 ± 83.6	53.7 ± 89.9	1.6e-172	2.8e-131	0.969	(L)	2.8e-131	0.969	(L)	0.76378	0.486	(N)
38	Grov	9	264	827.5 ± 163.6	61.8 ± 113.0	68.3 ± 120.9	5.7e-171	4.6e-130	0.967	(L)	4.6e-130	0.967	(L)	0.13181	0.522	(N)
39	Grov	9	324	968.9 ± 152.7	83.0 ± 140.5	86.8 ± 156.0	1.0e-180	1.8e-137	0.98	(L)	1.8e-137	0.98	(L)	0.56393	0.497	(N)
40	Grov	9	384	1089.0 ± 158.8	104.0 ± 181.9	106.2 ± 190.5	1.9e-182	1.0e-138	0.982	(L)	1.0e-138	0.982	(L)	0.80667	0.483	(N)
41	Grov	9	444	1284.6 ± 179.9	111.6 ± 196.8	120.0 ± 220.2	2.2e-182	1.0e-138	0.982	(L)	1.0e-138	0.982	(L)	0.59202	0.496	(N)
42	Grov	9	504	1436.5 ± 247.4	135.2 ± 227.5	156.8 ± 257.9	5.4e-176	9.9e-134	0.973	(L)	9.9e-134	0.973	(L)	0.94605	0.469	(N)
43	Grov	9	564	1537.1 ± 263.9	121.9 ± 210.0	143.0 ± 239.5	3.0e-176	9.8e-134	0.973	(L)	9.9e-134	0.973	(L)	0.98856	0.456	(N)
44	Grov	9	624	1724.9 ± 327.6	136.1 ± 265.8	140.4 ± 279.0	7.0e-171	4.6e-130	0.967	(L)	4.7e-130	0.967	(L)	0.71139	0.489	(N)
45	Grov	9	684	1895.1 ± 289.4	196.9 ± 304.6	199.7 ± 332.6	4.8e-179	3.3e-136	0.978	(L)	3.3e-136	0.978	(L)	0.5949	0.495	(N)

Table 10. Testing runtime results for the **Qwalk** program category.

							DGR	DG			DR			GR		
ID	Category	#Qubits	Depth	Default [s]	Greedy [s]	Random [s]	p-value	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude
0	Qwalk	3	14	0.4 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	2.2e-156	3.6e-121	0.947	(L)	3.2e-118	0.943	(L)	0.0795	0.527	(N)
1	Qwalk	3	21	0.3 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	3.2e-129	1.2e-99	0.905	(L)	1.2e-98	0.904	(L)	0.05597	0.53	(N)
2	Qwalk	3	28	0.2 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.24595	0.05989	0.53	(N)	0.10246	0.524	(N)	0.67428	0.491	(N)
3	Qwalk	3	35	0.3 ± 0.2	0.2 ± 0.2	0.2 ± 0.2	2.1e-08	1.5e-05	0.58	(S)	3.1e-09	0.612	(S)	0.08183	0.527	(N)
4	Qwalk	3	42	1.0 ± 0.2	0.3 ± 0.2	0.2 ± 0.2	1.8e-158	6.7e-120	0.947	(L)	1.9e-120	0.948	(L)	3.8e-04	0.565	(N)
5	Qwalk	3	49	0.5 ± 0.2	0.2 ± 0.1	0.2 ± 0.1	1.4e-119	1.0e-91	0.889	(L)	4.2e-92	0.89	(L)	0.40572	0.505	(N)
6	Qwalk	3	56	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.11308	0.08203	0.527	(N)	0.10554	0.524	(N)	0.01319	0.543	(N)
7	Qwalk	3	63	0.5 ± 0.3	0.3 ± 0.3	0.3 ± 0.3	1.2e-12	1.5e-07	0.598	(S)	2.3e-12	0.633	(S)	0.00157	0.557	(N)
8	Qwalk	3	70	1.5 ± 0.4	0.4 ± 0.3	0.4 ± 0.3	9.6e-154	1.0e-116	0.941	(L)	4.1e-118	0.943	(L)	0.2666	0.512	(N)
9	Qwalk	3	77	0.8 ± 0.3	0.3 ± 0.2	0.3 ± 0.2	8.3e-119	2.2e-90	0.886	(L)	3.3e-91	0.888	(L)	0.00728	0.547	(N)
10	Qwalk	3	84	0.4 ± 0.2	0.3 ± 0.2	0.3 ± 0.2	0.00743	0.02075	0.539	(N)	0.00277	0.553	(N)	0.03519	0.535	(N)
11	Qwalk	3	91	0.6 ± 0.4	0.4 ± 0.4	0.4 ± 0.4	0.00155	0.0039	0.551	(N)	2.2e-04	0.567	(N)	0.36425	0.507	(N)
12	Qwalk	3	98	2.0 ± 0.4	0.5 ± 0.4	0.5 ± 0.4	8.7e-162	7.0e-123	0.952	(L)	1.0e-122	0.952	(L)	6.7e-04	0.561	(N)
13	Qwalk	4	18	0.3 ± 0.2	0.2 ± 0.2	0.2 ± 0.2	1.7e-05	7.9e-05	0.573	(N)	7.3e-06	0.583	(S)	0.70417	0.49	(N)
14	Qwalk	4	27	0.5 ± 0.4	0.3 ± 0.3	0.4 ± 0.3	3.6e-12	9.1e-12	0.629	(S)	6.3e-09	0.61	(S)	0.89609	0.476	(N)
15	Qwalk	4	36	1.2 ± 0.8	0.4 ± 0.4	0.5 ± 0.5	2.1e-52	2.6e-41	0.758	(L)	1.7e-40	0.755	(L)	0.09555	0.525	(N)
16	Qwalk	4	45	0.8 ± 0.6	0.5 ± 0.5	0.5 ± 0.5	1.1e-10	1.8e-10	0.621	(S)	2.3e-08	0.605	(S)	0.32079	0.509	(N)
17	Qwalk	4	54	1.6 ± 1.2	0.6 ± 0.6	0.6 ± 0.6	2.7e-52	4.0e-40	0.754	(L)	7.2e-41	0.757	(L)	0.00848	0.546	(N)
18	Qwalk	4	63	1.0 ± 0.8	0.7 ± 0.7	0.7 ± 0.7	7.2e-13	9.2e-12	0.629	(S)	2.7e-10	0.619	(S)	0.16875	0.518	(N)
19	Qwalk	4	72	2.0 ± 1.5	0.7 ± 0.8	0.7 ± 0.8	2.9e-49	1.6e-35	0.738	(L)	2.6e-40	0.755	(L)	0.0026	0.554	(N)
20	Qwalk	4	81	1.3 ± 1.1	0.7 ± 0.8	0.7 ± 0.9	3.8e-18	2.3e-16	0.656	(S)	7.0e-14	0.642	(S)	0.29837	0.51	(N)
21	Qwalk	4	90	1.3 ± 1.0	0.5 ± 0.5	0.5 ± 0.5	8.2e-32	2.6e-24	0.694	(M)	6.1e-25	0.697	(M)	4.1e-04	0.564	(N)
22	Qwalk	4	99	3.0 ± 2.0	0.6 ± 0.5	0.6 ± 0.5	9.1e-82	5.4e-60	0.813	(L)	2.0e-63	0.822	(L)	7.1e-06	0.583	(S)
23	Qwalk	4	108	1.7 ± 1.1	0.6 ± 0.6	0.6 ± 0.5	9.4e-53	3.3e-40	0.754	(L)	7.0e-40	0.753	(L)	1.4e-05	0.58	(S)
24	Qwalk	4	117	3.4 ± 2.4	1.1 ± 1.2	1.1 ± 1.2	6.0e-63	4.3e-49	0.782	(L)	7.4e-49	0.782	(L)	0.31182	0.509	(N)
25	Qwalk	4	126	1.7 ± 1.3	1.1 ± 1.3	1.2 ± 1.3	2.8e-06	1.9e-05	0.579	(S)	1.8e-06	0.589	(S)	0.50036	0.5	(N)
26	Qwalk	5	22	0.5 ± 0.3	0.3 ± 0.3	0.3 ± 0.3	8.9e-13	2.4e-10	0.62	(S)	1.2e-11	0.629	(S)	0.50713	0.5	(N)
27	Qwalk	5	33	0.8 ± 0.5	0.5 ± 0.5	0.5 ± 0.5	4.6e-13	1.5e-09	0.614	(S)	5.4e-13	0.637	(S)	0.61007	0.495	(N)
28	Qwalk	5	44	1.8 ± 1.0	0.9 ± 1.1	0.9 ± 1.1	1.0e-23	5.8e-16	0.654	(S)	3.5e-22	0.685	(M)	0.06513	0.529	(N)
29	Qwalk	5	55	1.6 ± 1.3	1.0 ± 1.3	1.0 ± 1.3	3.7e-10	9.2e-08	0.6	(S)	5.1e-10	0.618	(S)	0.20521	0.516	(N)
30	Qwalk	5	66	4.3 ± 2.1	2.3 ± 2.3	2.3 ± 2.3	5.5e-31	1.3e-19	0.673	(M)	2.2e-30	0.719	(M)	0.43587	0.503	(N)
31	Qwalk	5	77	5.3 ± 2.6	1.6 ± 2.0	2.0 ± 2.6	5.6e-85	2.2e-74	0.851	(L)	3.9e-55	0.8	(L)	0.99627	0.448	(N)
32	Qwalk	5	88	9.2 ± 1.7	1.9 ± 2.5	1.9 ± 2.4	1.1e-172	2.3e-131	0.969	(L)	2.5e-131	0.969	(L)	0.09474	0.525	(N)
33	Qwalk	5	99	6.2 ± 3.5	1.9 ± 2.5	2.1 ± 2.7	1.2e-79	2.4e-63	0.823	(L)	3.7e-59	0.811	(L)	0.95303	0.468	(N)
34	Qwalk	5	110	7.5 ± 4.1	1.6 ± 2.1	1.6 ± 2.1	3.4e-98	2.4e-75	0.853	(L)	2.5e-75	0.853	(L)	0.07096	0.528	(N)
35	Qwalk	5	121	10.3 ± 4.0	2.6 ± 3.4	2.6 ± 3.4	3.2e-133	2.5e-101	0.911	(L)	2.0e-101	0.911	(L)	0.00711	0.547	(N)
36	Qwalk	5	132	13.3 ± 2.8	2.4 ± 3.0	2.4 ± 3.0	8.1e-168	1.1e-127	0.962	(L)	1.1e-127	0.962	(L)	0.09462	0.525	(N)
37	Qwalk	5	143	10.3 ± 5.0	5.9 ± 5.7	6.1 ± 5.8	7.2e-25	2.3e-15	0.651	(S)	2.3e-25	0.699	(M)	0.40798	0.504	(N)
38	Qwalk	5	154	15.2 ± 3.4	3.5 ± 4.6	3.6 ± 4.8	1.2e-160	7.0e-123	0.953	(L)	5.2e-121	0.95	(L)	0.99199	0.454	(N)

Table 11. Testing runtime results for the **Var** program category.

							DGR	DG			DR			GR		
ID	Category	#Qubits	Depth	Default [s]	Greedy [s]	Random [s]	p-value	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude
0	Var	2	6	0.3 ± 0.0	0.1 ± 0.1	0.1 ± 0.1	4.6e-145	3.5e-147	0.993	(L)	1.1e-74	0.849	(L)	0.99989	0.429	(N)
1	Var	2	6	0.3 ± 0.0	0.1 ± 0.1	0.1 ± 0.1	2.0e-121	8.7e-112	0.931	(L)	4.6e-71	0.842	(L)	0.99998	0.422	(S)
2	Var	2	7	0.3 ± 0.0	0.1 ± 0.1	0.1 ± 0.1	7.0e-130	2.6e-113	0.934	(L)	2.0e-83	0.871	(L)	0.99951	0.437	(N)
3	Var	2	7	0.3 ± 0.0	0.1 ± 0.1	0.1 ± 0.1	1.0e-136	1.5e-115	0.938	(L)	1.5e-93	0.894	(L)	0.90879	0.474	(N)
4	Var	3	3	0.1 ± 0.1	0.1 ± 0.0	0.1 ± 0.0	1.4e-37	2.3e-35	0.736	(M)	5.8e-25	0.697	(M)	0.49374	0.5	(N)
5	Var	3	4	0.2 ± 0.1	0.1 ± 0.0	0.1 ± 0.0	1.6e-45	1.6e-39	0.751	(L)	3.1e-32	0.726	(M)	0.80405	0.484	(N)
6	Var	3	3	0.2 ± 0.1	0.1 ± 0.0	0.1 ± 0.0	2.8e-45	2.7e-39	0.75	(L)	1.0e-31	0.724	(M)	0.94248	0.47	(N)
7	Var	3	4	0.2 ± 0.1	0.1 ± 0.0	0.1 ± 0.1	9.1e-44	8.3e-41	0.754	(L)	2.3e-28	0.711	(M)	0.866	0.479	(N)
8	Var	3	4	0.4 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	5.3e-193	1.2e-150	1.0	(L)	1.9e-143	0.989	(L)	0.93925	0.47	(N)
9	Var	3	4	0.5 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	6.2e-196	1.7e-150	1.0	(L)	2.4e-148	0.998	(L)	0.53582	0.498	(N)
10	Var	3	5	0.5 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	1.4e-194	1.3e-150	1.0	(L)	2.7e-146	0.994	(L)	0.36691	0.507	(N)
11	Var	3	5	0.5 ± 0.0	0.1 ± 0.1	0.1 ± 0.1	7.0e-198	5.4e-152	1.0	(L)	1.7e-149	0.999	(L)	0.99805	0.445	(N)
12	Var	4	69	1.3 ± 0.9	0.3 ± 0.2	0.4 ± 0.3	9.0e-67	3.6e-50	0.785	(L)	1.2e-43	0.766	(L)	1.0	0.349	(S)
13	Var	4	70	8.8 ± 1.1	0.3 ± 0.2	0.7 ± 0.6	1.3e-206	8.5e-150	1.0	(L)	5.0e-149	1.0	(L)	1.0	0.302	(M)
14	Var	4	70	8.7 ± 0.9	0.3 ± 0.2	0.7 ± 0.5	2.9e-203	6.1e-150	1.0	(L)	4.9e-149	1.0	(L)	1.0	0.338	(S)
15	Var	4	70	8.4 ± 0.5	0.3 ± 0.2	0.7 ± 0.6	6.8e-208	6.6e-150	1.0	(L)	5.0e-149	1.0	(L)	1.0	0.29	(M)
16	Var	4	11	0.9 ± 0.2	0.1 ± 0.1	0.2 ± 0.1	6.5e-167	2.9e-128	0.96	(L)	3.7e-127	0.96	(L)	0.54041	0.498	(N)
17	Var	4	11	0.9 ± 0.2	0.1 ± 0.1	0.2 ± 0.1	6.6e-166	1.9e-127	0.958	(L)	2.4e-126	0.958	(L)	0.03778	0.534	(N)
18	Var	4	12	0.9 ± 0.3	0.1 ± 0.1	0.2 ± 0.1	3.7e-143	1.6e-110	0.926	(L)	5.5e-109	0.925	(L)	0.12775	0.522	(N)
19	Var	4	12	0.9 ± 0.2	0.1 ± 0.1	0.2 ± 0.1	6.1e-169	1.8e-129	0.963	(L)	1.4e-128	0.963	(L)	0.10277	0.524	(N)
20	Var	5	11	0.4 ± 0.3	0.2 ± 0.2	0.2 ± 0.2	1.9e-36	1.0e-27	0.708	(M)	8.1e-22	0.683	(M)	1.0	0.365	(S)
21	Var	5	11	0.4 ± 0.3	0.2 ± 0.2	0.2 ± 0.2	4.9e-36	1.5e-27	0.708	(M)	2.1e-23	0.691	(M)	1.0	0.381	(S)
22	Var	5	12	0.4 ± 0.3	0.2 ± 0.2	0.2 ± 0.2	1.1e-34	5.7e-27	0.706	(M)	2.1e-24	0.695	(M)	1.0	0.405	(S)
23	Var	5	12	0.4 ± 0.3	0.2 ± 0.2	0.2 ± 0.2	3.8e-30	6.7e-24	0.693	(M)	5.7e-20	0.675	(M)	1.0	0.401	(S)
24	Var	6	8	0.3 ± 0.1	0.1 ± 0.1	0.2 ± 0.1	2.2e-73	6.1e-53	0.792	(L)	4.5e-56	0.802	(L)	1.0	0.38	(S)
25	Var	6	8	0.3 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	3.5e-185	3.8e-143	0.987	(L)	1.2e-133	0.971	(L)	1.0	0.379	(S)
26	Var	6	8	0.4 ± 0.1	0.1 ± 0.1	0.2 ± 0.1	2.0e-73	7.0e-54	0.795	(L)	1.8e-55	0.8	(L)	1.0	0.387	(S)
27	Var	6	8	0.3 ± 0.1	0.1 ± 0.1	0.2 ± 0.1	3.8e-64	4.4e-47	0.775	(L)	2.5e-45	0.77	(L)	1.0	0.362	(S)
28	Var	6	14	0.3 ± 0.0	0.1 ± 0.1	0.2 ± 0.1	3.7e-185	1.7e-149	0.998	(L)	8.3e-111	0.928	(L)	1.0	0.286	(M)
29	Var	6	14	0.3 ± 0.0	0.1 ± 0.1	0.1 ± 0.1	3.1e-189	2.1e-149	0.996	(L)	1.8e-125	0.955	(L)	1.0	0.319	(M)
30	Var	6	14	0.3 ± 0.0	0.1 ± 0.1	0.2 ± 0.1	7.5e-53	8.6e-38	0.745	(L)	3.7e-36	0.739	(L)	1.0	0.349	(S)
31	Var	6	14	0.3 ± 0.0	0.1 ± 0.1	0.2 ± 0.1	5.6e-187	2.3e-151	1.0	(L)	1.3e-110	0.927	(L)	1.0	0.278	(M)
32	Var	6	11	0.2 ± 0.2	0.2 ± 0.2	0.2 ± 0.2	1.1e-08	0.15011	0.52	(N)	0.82369	0.482	(N)	1.0	0.345	(S)
33	Var	6	12	0.2 ± 0.2	0.2 ± 0.2	0.2 ± 0.2	7.1e-07	0.02029	0.539	(N)	0.12465	0.522	(N)	1.0	0.365	(S)
34	Var	6	12	0.2 ± 0.2	0.2 ± 0.2	0.2 ± 0.2	1.2e-05	0.07803	0.527	(N)	0.35595	0.507	(N)	1.0	0.376	(S)
35	Var	6	12	0.2 ± 0.2	0.2 ± 0.2	0.2 ± 0.2	3.4e-07	4.4e-04	0.564	(N)	0.00893	0.546	(N)	1.0	0.384	(S)
36	Var	7	41	1.3 ± 1.1	0.3 ± 0.1	0.8 ± 0.6	7.2e-43	9.2e-28	0.709	(M)	1.0e-06	0.591	(S)	1.0	0.252	(L)
37	Var	7	41	1.2 ± 1.0	0.6 ± 0.6	1.7 ± 1.3	5.9e-46	4.4e-12	0.631	(S)	1.0	0.329	(M)	1.0	0.236	(L)
38	Var	7	41	1.3 ± 1.1	0.6 ± 0.6	0.7 ± 0.7	2.5e-24	4.0e-20	0.675	(M)	5.6e-17	0.66	(S)	0.99992	0.427	(N)
39	Var	7	41	1.4 ± 1.1	0.3 ± 0.1	0.8 ± 0.6	6.4e-48	1.4e-30	0.719	(M)	1.5e-09	0.614	(S)	1.0	0.241	(L)
40	Var	8	17	1.1 ± 1.1	0.4 ± 0.3	0.7 ± 0.6	2.6e-16	4.3e-11	0.625	(S)	1.5e-04	0.569	(N)	1.0	0.35	(S)
41	Var	8	17	1.2 ± 1.1	0.4 ± 0.3	0.7 ± 0.7	3.7e-22	1.8e-16	0.657	(S)	3.4e-07	0.596	(S)	1.0	0.345	(S)
42	Var	8	17	1.2 ± 1.2	0.5 ± 0.6	0.6 ± 0.6	1.8e-15	1.5e-12	0.634	(S)	1.3e-07	0.599	(S)	1.0	0.392	(S)
43	Var	8	17	1.2 ± 1.1	0.4 ± 0.3	0.7 ± 0.7	3.3e-20	8.0e-14	0.642	(S)	3.4e-07	0.596	(S)	1.0	0.343	(S)

Table 12. Testing runtime results for the **Gs** program category.

							DGR	DG			DR			GR		
ID	Category	#Qubits	Depth	Default [s]	Greedy [s]	Random [s]	p-value	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude
0	Gs	3	5	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	5.5e-36	2.1e-19	0.671	(M)	3.9e-30	0.717	(M)	3.7e-11	0.624	(S)
1	Gs	4	6	0.2 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	5.2e-121	1.8e-93	0.891	(L)	4.1e-91	0.887	(L)	1.6e-04	0.569	(N)
2	Gs	5	7	0.5 ± 0.2	0.1 ± 0.1	0.2 ± 0.2	2.4e-127	5.5e-100	0.906	(L)	1.0e-89	0.885	(L)	1.0	0.39	(S)
3	Gs	6	8	1.2 ± 0.3	0.2 ± 0.2	0.2 ± 0.2	1.3e-153	2.3e-116	0.94	(L)	4.9e-117	0.941	(L)	0.00193	0.555	(N)
4	Gs	7	9	2.7 ± 0.7	0.3 ± 0.4	0.3 ± 0.3	3.5e-161	6.3e-121	0.949	(L)	5.2e-121	0.949	(L)	6.2e-08	0.601	(S)
5	Gs	8	10	6.0 ± 1.7	0.4 ± 0.4	0.6 ± 0.7	1.1e-144	1.7e-110	0.929	(L)	2.5e-110	0.929	(L)	0.86791	0.479	(N)
6	Gs	9	11	13.3 ± 3.6	0.8 ± 0.9	1.0 ± 1.0	3.8e-153	4.8e-115	0.938	(L)	6.8e-115	0.938	(L)	1.0	0.402	(S)
7	Gs	10	12	29.5 ± 6.8	1.0 ± 1.0	2.0 ± 2.1	3.5e-162	4.0e-123	0.953	(L)	5.2e-123	0.953	(L)	0.99748	0.446	(N)
8	Gs	11	13	64.5 ± 13.3	2.0 ± 2.1	4.1 ± 4.5	6.1e-168	6.4e-128	0.962	(L)	9.3e-128	0.962	(L)	0.89935	0.475	(N)
9	Gs	12	14	142.3 ± 23.8	3.1 ± 2.4	10.1 ± 10.2	1.4e-177	4.1e-135	0.976	(L)	5.3e-135	0.976	(L)	0.87336	0.478	(N)
10	Gs	13	15	306.8 ± 57.7	6.4 ± 5.0	17.9 ± 20.2	3.9e-173	2.5e-131	0.969	(L)	2.6e-131	0.969	(L)	0.00555	0.549	(N)
11	Gs	14	16	682.3 ± 110.4	13.8 ± 10.6	48.6 ± 46.4	8.5e-210	2.8e-136	0.978	(L)	3.1e-136	0.978	(L)	1.0	0.157	(L)
12	Gs	15	17	1587.0 ± 303.5	25.7 ± 12.2	120.8 ± 101.5	3.5e-208	1.6e-132	0.971	(L)	1.6e-132	0.971	(L)	1.0	0.138	(L)
13	Gs	16	18	3670.9 ± 1059.6	54.2 ± 24.4	285.9 ± 215.1	2.9e-202	4.6e-124	0.956	(L)	4.7e-124	0.956	(L)	1.0	0.111	(L)

Table 13. Mutation scores for the **Grov** program category. Table 1/3.

								DGR	DG			DR			GR		
ID	Mutant Type	Category	#Qubits	Depth	Default [%]	Greedy [%]	Random [%]	p-value	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude
0	all	Grov	6	178	71.6 ± 6.3	78.7 ± 5.9	73.1 ± 8.7	6.7e-04	0.99994	0.222	(L)	0.81456	0.436	(N)	0.00584	0.683	(M)
0	X	Grov	6	178	100.0 ± 0.0	56.7 ± 21.7	54.4 ± 28.3	1.5e-12	3.5e-12	0.967	(L)	6.4e-11	0.933	(L)	0.39383	0.519	(N)
0	Z	Grov	6	178	0.0 ± 0.0	48.9 ± 21.0	34.4 ± 23.9	1.3e-12	1.0	0.017	(L)	1.0	0.117	(L)	0.0123	0.654	(S)
0	R_y	Grov	6	178	85.9 ± 10.5	95.9 ± 6.2	92.2 ± 7.8	2.7e-04	0.99995	0.228	(L)	0.99161	0.331	(M)	0.02638	0.629	(S)
1	all	Grov	6	30	46.2 ± 7.2	73.6 ± 9.2	73.3 ± 10.2	9.2e-14	1.0	0.001	(L)	1.0	0.007	(L)	0.44488	0.511	(N)
1	X	Grov	6	30	100.0 ± 0.0	62.2 ± 27.3	47.8 ± 29.9	2.2e-11	2.1e-09	0.883	(L)	2.0e-11	0.95	(L)	0.03642	0.628	(S)
1	Z	Grov	6	30	3.3 ± 10.2	33.3 ± 24.8	50.0 ± 28.7	7.7e-10	1.0	0.157	(L)	1.0	0.09	(L)	0.99201	0.331	(M)
1	R_y	Grov	6	30	42.6 ± 12.1	90.7 ± 7.8	89.6 ± 9.2	3.2e-14	1.0	0.0	(L)	1.0	0.001	(L)	0.36254	0.525	(N)
2	all	Grov	6	121	66.0 ± 5.4	75.8 ± 8.5	76.4 ± 8.3	5.5e-07	1.0	0.178	(L)	1.0	0.144	(L)	0.52733	0.496	(N)
2	X	Grov	6	121	100.0 ± 0.0	63.3 ± 28.2	44.4 ± 33.1	3.4e-11	2.0e-09	0.883	(L)	7.6e-11	0.933	(L)	0.01127	0.664	(S)
2	Z	Grov	6	121	0.0 ± 0.0	36.7 ± 28.2	58.9 ± 32.4	8.3e-12	1.0	0.117	(L)	1.0	0.05	(L)	0.99645	0.308	(M)
2	R_y	Grov	6	121	76.7 ± 8.9	93.0 ± 9.0	93.0 ± 6.8	1.9e-09	1.0	0.119	(L)	1.0	0.094	(L)	0.35012	0.527	(N)
3	all	Grov	6	42	81.3 ± 4.1	73.8 ± 9.3	76.4 ± 9.9	4.6e-04	1.3e-05	0.789	(L)	0.005	0.679	(M)	0.78204	0.444	(N)
3	X	Grov	6	42	100.0 ± 0.0	47.8 ± 27.2	67.8 ± 25.5	3.7e-12	1.2e-12	0.983	(L)	1.8e-08	0.85	(L)	0.9948	0.322	(M)
3	Z	Grov	6	42	8.9 ± 21.3	53.3 ± 33.4	32.2 ± 33.3	1.4e-06	1.0	0.147	(L)	0.99944	0.286	(M)	0.00833	0.674	(M)
3	R_y	Grov	6	42	99.3 ± 2.8	89.3 ± 11.5	94.1 ± 9.6	1.2e-04	1.3e-05	0.76	(L)	0.0023	0.653	(S)	0.9631	0.378	(S)
4	all	Grov	6	48	70.9 ± 5.9	78.9 ± 10.4	77.6 ± 9.8	0.00131	0.9996	0.257	(L)	0.99828	0.287	(M)	0.30241	0.538	(N)
4	X	Grov	6	48	100.0 ± 0.0	64.4 ± 31.5	64.4 ± 31.5	2.8e-07	1.5e-07	0.817	(L)	1.5e-07	0.817	(L)	0.50313	0.5	(N)
4	Z	Grov	6	48	1.1 ± 6.1	42.2 ± 27.6	38.9 ± 27.8	4.1e-10	1.0	0.094	(L)	1.0	0.112	(L)	0.30517	0.536	(N)
4	R_y	Grov	6	48	84.4 ± 9.5	95.9 ± 7.4	94.8 ± 7.0	1.7e-06	1.0	0.179	(L)	0.99998	0.209	(L)	0.20538	0.552	(N)
5	all	Grov	6	54	80.0 ± 2.5	71.1 ± 9.6	72.9 ± 10.5	2.3e-05	2.2e-06	0.826	(L)	2.2e-04	0.744	(L)	0.7597	0.449	(N)
5	X	Grov	6	54	100.0 ± 0.0	45.6 ± 30.9	53.3 ± 29.8	2.6e-11	6.9e-11	0.933	(L)	2.3e-10	0.917	(L)	0.85015	0.427	(N)
5	Z	Grov	6	54	2.2 ± 8.5	34.4 ± 28.3	33.3 ± 27.7	2.7e-07	1.0	0.173	(L)	1.0	0.174	(L)	0.44067	0.511	(N)
5	R_y	Grov	6	54	99.3 ± 2.8	91.9 ± 10.1	92.6 ± 10.7	7.3e-04	4.2e-05	0.738	(L)	0.0017	0.659	(S)	0.72243	0.461	(N)
6	all	Grov	6	66	66.4 ± 5.9	77.8 ± 8.1	77.8 ± 7.9	3.4e-08	1.0	0.132	(L)	1.0	0.128	(L)	0.38484	0.522	(N)
6	X	Grov	6	66	100.0 ± 0.0	70.0 ± 26.8	67.8 ± 28.3	7.1e-08	5.0e-08	0.833	(L)	5.4e-08	0.833	(L)	0.38491	0.521	(N)
6	Z	Grov	6	66	3.3 ± 10.2	32.2 ± 27.0	34.4 ± 23.9	2.1e-07	1.0	0.188	(L)	1.0	0.153	(L)	0.6842	0.467	(N)
6	R_y	Grov	6	66	76.3 ± 9.1	95.6 ± 7.5	95.6 ± 6.3	6.5e-12	1.0	0.068	(L)	1.0	0.054	(L)	0.37726	0.52	(N)
7	all	Grov	6	72	63.3 ± 5.5	77.3 ± 10.0	76.4 ± 9.4	2.4e-08	1.0	0.123	(L)	1.0	0.122	(L)	0.40423	0.518	(N)
7	X	Grov	6	72	100.0 ± 0.0	51.1 ± 28.7	57.8 ± 27.6	9.3e-12	1.9e-11	0.95	(L)	2.1e-10	0.917	(L)	0.80202	0.441	(N)
7	Z	Grov	6	72	1.1 ± 6.1	53.3 ± 29.8	43.3 ± 21.7	4.5e-12	1.0	0.058	(L)	1.0	0.06	(L)	0.09168	0.593	(S)
7	R_y	Grov	6	72	71.9 ± 8.6	94.1 ± 9.6	93.7 ± 9.5	1.8e-11	1.0	0.067	(L)	1.0	0.068	(L)	0.41702	0.514	(N)
8	all	Grov	6	78	55.3 ± 4.3	74.2 ± 11.7	76.4 ± 10.6	7.9e-11	1.0	0.082	(L)	1.0	0.048	(L)	0.78096	0.443	(N)
8	X	Grov	6	78	100.0 ± 0.0	57.8 ± 31.5	65.6 ± 29.7	4.2e-09	2.3e-09	0.883	(L)	1.9e-08	0.85	(L)	0.84245	0.429	(N)
8	Z	Grov	6	78	2.2 ± 8.5	43.3 ± 29.2	41.1 ± 28.6	1.5e-09	1.0	0.104	(L)	1.0	0.121	(L)	0.4096	0.517	(N)
8	R_y	Grov	6	78	58.1 ± 7.5	90.0 ± 9.8	91.9 ± 9.2	7.6e-14	1.0	0.012	(L)	1.0	0.006	(L)	0.77775	0.447	(N)
9	all	Grov	6	125	46.4 ± 6.4	66.2 ± 10.8	66.0 ± 9.3	2.1e-11	1.0	0.062	(L)	1.0	0.038	(L)	0.44597	0.511	(N)
9	X	Grov	6	125	13.3 ± 20.7	11.1 ± 20.2	14.4 ± 22.6	0.81593	0.30623	0.531	(N)	0.53906	0.494	(N)	0.72495	0.464	(N)
9	Z	Grov	6	125	0.0 ± 0.0	82.2 ± 21.0	66.7 ± 24.8	2.7e-15	1.0	0.0	(L)	1.0	0.0	(L)	0.00692	0.671	(M)
9	R_y	Grov	6	125	73.0 ± 7.5	79.3 ± 12.3	83.0 ± 11.2	0.0024	0.98803	0.339	(S)	0.99976	0.251	(L)	0.85435	0.424	(S)
10	all	Grov	6	90	80.0 ± 2.5	71.8 ± 9.9	71.1 ± 11.4	1.9e-04	2.7e-05	0.777	(L)	3.2e-04	0.732	(M)	0.461	0.508	(N)
10	X	Grov	6	90	100.0 ± 0.0	48.9 ± 28.7	48.9 ± 28.7	2.7e-12	2.0e-11	0.95	(L)	2.0e-11	0.95	(L)	0.50314	0.5	(N)
10	Z	Grov	6	90	2.2 ± 8.5	34.4 ± 28.3	34.4 ± 28.3	2.7e-07	1.0	0.173	(L)	1.0	0.173	(L)	0.50313	0.5	(N)
10	R_y	Grov	6	90	99.3 ± 2.8	91.9 ± 8.7	90.7 ± 11.0	3.7e-05	1.7e-05	0.754	(L)	1.7e-05	0.756	(L)	0.43613	0.512	(N)
11	all	Grov	7	57	50.0 ± 6.9	77.3 ± 9.0	70.9 ± 12.4	1.8e-12	1.0	0.012	(L)	1.0	0.07	(L)	0.01182	0.667	(M)
11	X	Grov	7	57	100.0 ± 0.0	64.4 ± 26.2	54.4 ± 27.0	1.4e-10	2.0e-09	0.883	(L)	2.0e-10	0.917	(L)	0.05997	0.61	(S)
11	Z	Grov	7	57	0.0 ± 0.0	42.2 ± 30.2	22.2 ± 29.5	2.5e-08	1.0	0.117	(L)	0.99997	0.283	(M)	0.00506	0.683	(M)
11	R_y	Grov	7	57	50.0 ± 11.6	93.3 ± 9.9	92.6 ± 10.2	1.6e-14	1.0	0.003	(L)	1.0	0.003	(L)	0.38944	0.519	(N)
12	all	Grov	7	36	74.7 ± 6.2	76.2 ± 8.7	75.8 ± 12.4	0.654	0.75816	0.45	(N)	0.81216	0.436	(N)	0.56904	0.488	(N)
12	X	Grov	7	36	100.0 ± 0.0	72.2 ± 26.4	52.2 ± 31.2	4.0e-10	3.8e-07	0.8	(L)	6.6e-11	0.933	(L)	0.00807	0.672	(M)
12	Z	Grov	7	36	2.2 ± 8.5	31.1 ± 26.2	47.8 ± 25.8	7.2e-10	1.0	0.191	(L)	1.0	0.068	(L)	0.98905	0.339	(S)
12	R_y	Grov	7	36	90.4 ± 9.1	92.6 ± 10.2	93.0 ± 9.9	0.30547	0.89444	0.414	(S)	0.91932	0.404	(S)	0.54591	0.493	(N)
13	all	Grov	7	48	73.3 ± 5.5	76.4 ± 11.6	76.9 ± 11.2	0.28686	0.93536	0.39	(S)	0.89358	0.41	(S)	0.49101	0.502	(N)
13	X	Grov	7	48	100.0 ± 0.0	53.3 ± 28.5	54.4 ± 28.3	6.4e-11	2.2e-10	0.917	(L)	2.2e-10	0.917	(L)	0.575	0.487	(N)
13	Z	Grov	7	48	5.6 ± 12.6	43.3 ± 31.7	44.4 ± 28.1	9.5e-09	1.0	0.153	(L)	1.0	0.108	(L)	0.55743	0.491	(N)
13	R_y	Grov	7	48	87.0 ± 7.8	95.2 ± 8.1	95.2 ± 7.5	3.5e-05	0.99994	0.232	(L)	0.99995	0.231	(L)	0.44262	0.509	(N)
14	all	Grov	7	205	64.7 ± 5.6	76.0 ± 9.0	77.6 ± 7.3	2.8e-08	1.0	0.158	(L)	1.0	0.098	(L)	0.74488	0.453	(N)
14	X	Grov	7	205	100.0 ± 0.0	48.9 ± 33.6	67.8 ± 28.3	1.1e-09	7.7e-10	0.9	(L)	5.4e-08	0.833	(L)	0.98791	0.338	(S)
14	Z	Grov	7	205	3.3 ± 10.2	43.3 ± 29.2	33.3 ± 23.2	1.3e-08	1.0	0.128	(L)	1.0	0.155	(L)	0.08418	0.597	(S)
14	R_y	Grov	7	205	73.3 ± 8.0	95.9 ± 6.2	95.6 ± 7.5	3.3e-13	1.0	0.03	(L)	1.0	0.043	(L)	0.53611	0.495	(N)
15	all	Grov	7	492	69.6 ± 6.5	79.8 ± 10.0	75.8 ± 10.7	4.4e-05	0.99999	0.177	(L)	0.99775	0.293	(M)	0.04891	0.622	(S)
15	X	Grov	7	492	100.0 ± 0.0	75.6 ± 24.7	64.4 ± 30.2	5.6e-08	3.3e-07	0.8	(L)	2.0e-08	0.85	(L)	0.07047	0.603	(S)
15	Z	Grov	7	492	3.3 ± 10.2	38.9 ± 31.7	31.1 ± 27.6	1.1e-06	1.0	0.18	(L)	1.0	0.205	(L)	0.16698	0.569	(N)
15	R_y	Grov	7	492	81.5 ± 9.4	94.8 ± 9.1	94.4 ± 8.1	3.8e-08	1.0	0.142	(L)	1.0	0.151	(L)	0.32203	0.53	(N)
16	all	Grov	7	96	67.1 ± 6.5	76.9 ± 8.3	78.0 ± 8.1	8.7e-07	0.99999	0.179	(L)	1.0	0.154	(L)	0.70265	0.462	(N)
16	X	Grov	7	96	100.0 ± 0.0	72.2 ± 23.3	60.0 ± 22.1	1.7e-10	4.7e-08	0.833	(L)	5.2e-11	0.933	(L)	0.02192	0.639	(S)
16	Z	Grov	7	96	1.1 ± 6.1	25.6 ± 29.9	41.1 ± 35.8	7.3e-07	0.99998	0.263	(L)	1.0	0.161	(L)	0.95884	0.377	(S)
16	R_y	Grov	7	96	78.1 ± 9.9	95.6 ± 6.3	96.3 ± 7.3	1.2e-10	1.0	0.093	(L)	1.0	0.092	(L)	0.786	0.452	(N)
17	all	Grov	7	108	66.7 ± 5.0	78.7 ± 7.1	77.8 ± 9.0	3.1e-09	1.0	0.089	(L)	1.0	0.118	(L)	0.48468	0.503	(N)
17	X	Grov	7	108	100.0 ± 0.0	51.1 ± 32.4	66.7 ± 31.6	7.0e-10	2.4e-10	0.917	(L)	5.2e-08	0.833	(L)	0.97329	0.362	(S)
17	Z	Grov	7	108	0.0 ± 0.0	54.4 ± 29.7	34.4 ± 28.3	1.5e-11	1.0	0.05	(L)	1.0	0.133	(L)	0.00447	0.687	(M)
17	R_y	Grov	7	108	77.8 ± 8.3	95.9 ± 5.4	95.9 ± 6.2	3.8e-12	1.0	0.053	(L)	1.0	0.062	(L)	0.57071	0.489	(N)
18	all	Grov	7	120	67.6 ± 6.2	76.4 ± 9.5	76.7 ± 7.6	2.6e-05	0.99987	0.234	(L)	0.99999	0.186	(L)	0.47884	0.504	(N)
18	X	Grov	7	120	100.0 ± 0.0	35.6 ± 26.2	71.1 ± 24.3	6.2e-14	3.9e-13	1.0	(L)	4.9e-08	0.833	(L)	1.0	0.184	(L)
18	Z	Grov	7	120	1.1 ± 6.1	58.9 ± 25.8	25.6 ± 24.3	3.2e-12	1.0	0.038	(L)	1.0	0.214	(L)	7.2e-06	0.81	(L)
18	R_y	Grov	7	120	78.9 ± 9.8	95.9 ± 6.2	95.6 ± 6.9	5.8e-10	1.0	0.1	(L)	1.0	0.111	(L)	0.46787	0.506	(N)
19	all	Grov	7	132	68.4 ± 5.5	78.9 ± 9.3	79.6 ± 8.7	8.0e-07	1.0	0.174	(L)	1.0	0.153	(L)	0.56037	0.489	(N)
19	X	Grov	7	132	100.0 ± 0.0	65.6 ± 23.9	75.6 ± 21.3	5.1e-09	1.9e-09	0.883	(L)	1.2e-07	0.817	(L)	0.95115	0.387	(S)
19	Z	Grov	7	132	0.0 ± 0.0	44.4 ± 28.1	35.6 ± 30.2	7.2e-10	1.0	0.083	(L)	1.0	0.15	(L)	0.1072	0.589	(S)
19	R_y	Grov	7	132	80.7 ± 9.2	94.8 ± 7.0	95.6 ± 5.5	3.1e-09	1.0	0.132	(L)	1.0	0.107	(L)	0.58534	0.487	(N)
20	all	Grov	7	144	67.3 ± 5.4	78.4 ± 8.9	76.2 ± 11.7	2.6e-05	1.0	0.157	(L)	0.99889	0.277	(M)	0.19373	0.564	(N)
20	X	Grov	7	144	100.0 ± 0.0	42.2 ± 31.5	58.9 ± 27.2	9.5e-12	2.2e-11	0.95	(L)	6.9e-10	0.9	(L)	0.98041	0.353	(S)
20	Z	Grov	7	144	0.0 ± 0.0	65.6 ± 28.3	40.0 ± 34.4	7.3e-12	1.0	0.033	(L)	1.0	0.15	(L)	0.00171	0.712	(M)
20	R_y	Grov	7	144	78.9 ± 8.9	94.8 ± 5.6	94.1 ± 7.6	7.6e-10	1.0	0.087	(L)	1.0	0.118	(L)	0.46308	0.507	(N)

Table 14. Mutation scores for the **Grov** program category. Table 2/3.

								DGR	DG			DR			GR		
ID	Mutant Type	Category	#Qubits	Depth	Default [%]	Greedy [%]	Random [%]	p-value	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude
21	all	Grov	7	156	69.3 ± 7.1	78.7 ± 10.3	75.3 ± 8.4	4.7e-04	0.99985	0.233	(L)	0.99733	0.297	(M)	0.06618	0.611	(S)
21	X	Grov	7	156	100.0 ± 0.0	57.8 ± 31.5	70.0 ± 26.8	4.7e-09	2.3e-09	0.883	(L)	5.0e-08	0.833	(L)	0.94031	0.39	(S)
21	Z	Grov	7	156	3.3 ± 10.2	50.0 ± 28.7	23.3 ± 23.4	4.2e-09	1.0	0.103	(L)	0.99995	0.26	(L)	2.1e-04	0.752	(L)
21	R_y	Grov	7	156	81.1 ± 10.6	95.2 ± 5.6	94.4 ± 7.6	8.1e-08	1.0	0.144	(L)	1.0	0.164	(L)	0.4591	0.507	(N)
22	all	Grov	8	79	78.4 ± 2.9	79.3 ± 10.1	77.1 ± 10.5	0.58151	0.76934	0.449	(N)	0.25809	0.546	(N)	0.19717	0.563	(N)
22	X	Grov	8	79	100.0 ± 0.0	67.8 ± 27.0	60.0 ± 28.2	1.5e-09	1.8e-08	0.85	(L)	6.8e-10	0.9	(L)	0.14235	0.576	(S)
22	Z	Grov	8	79	0.0 ± 0.0	41.1 ± 29.9	36.7 ± 28.2	2.6e-09	1.0	0.117	(L)	1.0	0.133	(L)	0.28967	0.54	(N)
22	R_y	Grov	8	79	97.4 ± 4.8	95.9 ± 6.2	96.3 ± 7.9	0.62216	0.18239	0.554	(N)	0.44805	0.508	(N)	0.76524	0.458	(N)
23	all	Grov	8	54	76.9 ± 3.8	80.4 ± 12.1	81.3 ± 8.6	0.0311	0.98634	0.342	(S)	0.99239	0.327	(M)	0.51808	0.497	(N)
23	X	Grov	8	54	100.0 ± 0.0	52.2 ± 33.5	65.6 ± 29.7	5.6e-10	2.3e-10	0.917	(L)	1.9e-08	0.85	(L)	0.93805	0.391	(S)
23	Z	Grov	8	54	0.0 ± 0.0	61.1 ± 29.1	51.1 ± 27.3	3.2e-13	1.0	0.033	(L)	1.0	0.033	(L)	0.07337	0.603	(S)
23	R_y	Grov	8	54	94.8 ± 6.3	96.3 ± 7.9	96.7 ± 5.9	0.26811	0.92536	0.411	(S)	0.90247	0.419	(S)	0.42622	0.511	(N)
24	all	Grov	8	84	80.2 ± 4.1	80.4 ± 8.2	80.4 ± 5.8	0.94606	0.42458	0.514	(N)	0.64425	0.476	(N)	0.58522	0.485	(N)
24	X	Grov	8	84	100.0 ± 0.0	68.9 ± 26.2	76.7 ± 25.0	4.3e-07	5.3e-08	0.833	(L)	2.4e-06	0.767	(L)	0.88121	0.418	(S)
24	Z	Grov	8	84	7.8 ± 16.8	44.4 ± 30.7	32.2 ± 28.3	2.4e-06	1.0	0.168	(L)	0.99995	0.241	(L)	0.04993	0.617	(S)
24	R_y	Grov	8	84	97.8 ± 4.5	96.3 ± 5.3	97.8 ± 4.5	0.38602	0.12542	0.567	(N)	0.50426	0.5	(N)	0.87852	0.433	(N)
25	all	Grov	8	114	76.4 ± 4.5	79.3 ± 8.6	78.9 ± 7.8	0.21298	0.88246	0.417	(S)	0.96822	0.369	(S)	0.56361	0.489	(N)
25	X	Grov	8	114	100.0 ± 0.0	52.2 ± 29.9	64.4 ± 27.6	2.8e-10	2.3e-10	0.917	(L)	6.4e-09	0.867	(L)	0.94781	0.385	(S)
25	Z	Grov	8	114	3.3 ± 10.2	53.3 ± 33.4	42.2 ± 27.6	5.8e-10	1.0	0.092	(L)	1.0	0.115	(L)	0.09908	0.592	(S)
25	R_y	Grov	8	114	93.0 ± 6.8	97.0 ± 5.0	95.9 ± 5.4	0.0377	0.993	0.341	(S)	0.95668	0.388	(S)	0.20712	0.55	(N)
26	all	Grov	8	144	76.7 ± 4.5	76.4 ± 9.4	75.8 ± 10.6	0.90891	0.27068	0.544	(N)	0.49693	0.501	(N)	0.53017	0.495	(N)
26	X	Grov	8	144	100.0 ± 0.0	56.7 ± 30.5	52.2 ± 28.6	2.5e-11	2.1e-10	0.917	(L)	6.7e-11	0.933	(L)	0.232	0.552	(N)
26	Z	Grov	8	144	1.1 ± 6.1	42.2 ± 30.2	42.2 ± 31.5	1.1e-09	1.0	0.111	(L)	1.0	0.111	(L)	0.47184	0.506	(N)
26	R_y	Grov	8	144	94.1 ± 7.0	94.4 ± 7.0	94.8 ± 8.1	0.76387	0.59606	0.484	(N)	0.76502	0.453	(N)	0.69369	0.468	(N)
27	all	Grov	8	174	85.3 ± 5.4	78.0 ± 9.0	77.8 ± 6.9	2.8e-05	1.8e-04	0.755	(L)	9.4e-06	0.806	(L)	0.33291	0.531	(N)
27	X	Grov	8	174	100.0 ± 0.0	48.9 ± 28.7	56.7 ± 34.1	1.0e-10	2.0e-11	0.95	(L)	7.3e-09	0.867	(L)	0.82753	0.433	(N)
27	Z	Grov	8	174	26.7 ± 26.8	58.9 ± 28.6	44.4 ± 28.1	1.8e-04	0.99996	0.215	(L)	0.99341	0.327	(M)	0.02322	0.642	(S)
27	R_y	Grov	8	174	100.0 ± 0.0	94.1 ± 7.0	95.9 ± 6.2	1.6e-04	1.3e-05	0.733	(M)	3.1e-04	0.667	(M)	0.86224	0.43	(N)
28	all	Grov	8	204	76.2 ± 4.9	78.2 ± 8.4	77.1 ± 8.7	0.67826	0.81909	0.436	(N)	0.63596	0.476	(N)	0.31347	0.536	(N)
28	X	Grov	8	204	100.0 ± 0.0	61.1 ± 27.8	74.4 ± 22.6	2.0e-09	6.4e-10	0.9	(L)	1.3e-07	0.817	(L)	0.96997	0.371	(S)
28	Z	Grov	8	204	2.2 ± 8.5	41.1 ± 24.3	21.1 ± 20.5	7.3e-10	1.0	0.074	(L)	0.99998	0.248	(L)	7.2e-04	0.714	(M)
28	R_y	Grov	8	204	93.0 ± 7.4	96.3 ± 6.1	96.7 ± 6.6	0.0469	0.97023	0.377	(S)	0.98736	0.356	(S)	0.68402	0.473	(N)
29	all	Grov	8	234	72.9 ± 5.2	78.2 ± 7.4	78.4 ± 8.0	0.00456	0.99803	0.292	(M)	0.99764	0.296	(M)	0.56968	0.488	(N)
29	X	Grov	8	234	100.0 ± 0.0	64.4 ± 30.2	60.0 ± 26.8	4.5e-09	2.0e-08	0.85	(L)	2.1e-09	0.883	(L)	0.21958	0.556	(N)
29	Z	Grov	8	234	1.1 ± 6.1	37.8 ± 25.9	43.3 ± 25.0	1.4e-10	1.0	0.112	(L)	1.0	0.077	(L)	0.81528	0.438	(N)
29	R_y	Grov	8	234	87.8 ± 8.4	96.3 ± 5.3	96.3 ± 5.3	1.8e-05	0.99996	0.228	(L)	0.99996	0.228	(L)	0.50361	0.5	(N)
30	all	Grov	8	264	72.4 ± 4.9	78.9 ± 7.8	80.2 ± 7.7	5.9e-05	0.99972	0.258	(L)	0.99998	0.203	(L)	0.78144	0.444	(N)
30	X	Grov	8	264	100.0 ± 0.0	67.8 ± 29.7	67.8 ± 29.7	7.4e-08	5.2e-08	0.833	(L)	5.2e-08	0.833	(L)	0.50315	0.5	(N)
30	Z	Grov	8	264	2.2 ± 8.5	41.1 ± 20.9	40.0 ± 22.1	3.9e-11	1.0	0.072	(L)	1.0	0.089	(L)	0.43742	0.511	(N)
30	R_y	Grov	8	264	86.7 ± 8.5	95.2 ± 7.0	97.8 ± 4.5	3.6e-07	0.99994	0.232	(L)	1.0	0.15	(L)	0.93757	0.41	(S)
31	all	Grov	8	294	74.7 ± 5.6	73.8 ± 8.6	79.3 ± 9.5	0.0039	0.34894	0.528	(N)	0.99802	0.292	(M)	0.99786	0.293	(M)
31	X	Grov	8	294	100.0 ± 0.0	58.9 ± 31.2	65.6 ± 27.0	4.9e-09	6.9e-09	0.867	(L)	6.2e-09	0.867	(L)	0.8131	0.437	(N)
31	Z	Grov	8	294	1.1 ± 6.1	28.9 ± 27.3	43.3 ± 26.5	1.3e-09	1.0	0.197	(L)	1.0	0.077	(L)	0.98214	0.353	(S)
31	R_y	Grov	8	294	90.7 ± 8.8	93.7 ± 9.5	95.9 ± 8.0	0.02911	0.94441	0.391	(S)	0.99542	0.326	(M)	0.86152	0.433	(N)
32	all	Grov	8	324	72.4 ± 7.6	76.2 ± 10.9	77.3 ± 10.0	0.0982	0.94901	0.381	(S)	0.97834	0.352	(S)	0.69355	0.463	(N)
32	X	Grov	8	324	100.0 ± 0.0	57.8 ± 32.7	57.8 ± 27.6	7.0e-10	7.1e-09	0.867	(L)	2.1e-10	0.917	(L)	0.50311	0.5	(N)
32	Z	Grov	8	324	4.4 ± 11.5	42.2 ± 30.2	44.4 ± 25.3	2.5e-09	1.0	0.13	(L)	1.0	0.104	(L)	0.73549	0.457	(N)
32	R_y	Grov	8	324	85.9 ± 11.3	93.7 ± 9.1	94.8 ± 7.6	0.00202	0.99729	0.304	(M)	0.99926	0.278	(M)	0.6404	0.477	(N)
33	all	Grov	8	354	74.0 ± 6.2	80.0 ± 11.2	80.4 ± 8.4	0.00152	0.99927	0.268	(M)	0.99891	0.278	(M)	0.3806	0.523	(N)
33	X	Grov	8	354	100.0 ± 0.0	57.8 ± 28.9	67.8 ± 30.9	2.0e-09	2.0e-10	0.917	(L)	1.5e-07	0.817	(L)	0.91495	0.403	(S)
33	Z	Grov	8	354	5.6 ± 12.6	52.2 ± 25.8	44.4 ± 29.5	1.1e-09	1.0	0.072	(L)	1.0	0.144	(L)	0.16957	0.568	(N)
33	R_y	Grov	8	354	88.1 ± 10.1	96.7 ± 7.8	96.7 ± 7.8	6.3e-05	0.99985	0.257	(L)	0.99985	0.257	(L)	0.50423	0.5	(N)
34	all	Grov	9	101	83.6 ± 4.5	79.6 ± 8.7	81.3 ± 8.1	0.0829	0.00845	0.666	(M)	0.1688	0.568	(N)	0.84811	0.426	(S)
34	X	Grov	9	101	100.0 ± 0.0	61.1 ± 29.1	72.2 ± 23.3	4.3e-09	2.2e-09	0.883	(L)	4.7e-08	0.833	(L)	0.93027	0.397	(S)
34	Z	Grov	9	101	17.8 ± 22.7	51.1 ± 30.0	45.6 ± 27.0	2.5e-05	0.99998	0.204	(L)	0.99992	0.232	(L)	0.25629	0.547	(N)
34	R_y	Grov	9	101	100.0 ± 0.0	95.2 ± 7.0	96.3 ± 7.9	0.00194	1.5e-04	0.683	(M)	0.00277	0.617	(S)	0.84666	0.439	(N)
35	all	Grov	9	166	78.9 ± 3.9	80.0 ± 9.1	79.6 ± 8.7	0.76408	0.72475	0.459	(N)	0.76443	0.451	(N)	0.48485	0.503	(N)
35	X	Grov	9	166	100.0 ± 0.0	58.9 ± 29.9	70.0 ± 29.5	3.0e-08	2.3e-09	0.883	(L)	9.9e-07	0.783	(L)	0.91376	0.403	(S)
35	Z	Grov	9	166	2.2 ± 8.5	47.8 ± 29.9	34.4 ± 34.4	1.5e-08	1.0	0.1	(L)	1.0	0.208	(L)	0.03927	0.627	(S)
35	R_y	Grov	9	166	97.4 ± 5.6	97.8 ± 4.5	97.8 ± 5.4	0.94401	0.52971	0.497	(N)	0.62924	0.484	(N)	0.60843	0.487	(N)
36	all	Grov	9	144	80.7 ± 2.0	76.9 ± 9.7	78.9 ± 9.9	0.26349	0.03653	0.613	(S)	0.18731	0.56	(N)	0.75388	0.451	(N)
36	X	Grov	9	144	100.0 ± 0.0	58.9 ± 33.5	55.6 ± 28.1	2.6e-10	7.1e-09	0.867	(L)	6.1e-11	0.933	(L)	0.30838	0.536	(N)
36	Z	Grov	9	144	3.3 ± 10.2	34.4 ± 30.9	47.8 ± 31.2	5.0e-08	1.0	0.202	(L)	1.0	0.123	(L)	0.95572	0.378	(S)
36	R_y	Grov	9	144	100.0 ± 0.0	97.0 ± 5.0	97.0 ± 5.8	0.01132	0.00135	0.633	(S)	0.00276	0.617	(S)	0.58943	0.488	(N)
37	all	Grov	9	204	89.6 ± 4.9	80.9 ± 8.9	80.2 ± 10.0	2.5e-05	2.2e-05	0.797	(L)	4.4e-05	0.784	(L)	0.42468	0.514	(N)
37	X	Grov	9	204	100.0 ± 0.0	70.0 ± 23.7	65.6 ± 23.9	1.3e-09	1.7e-08	0.85	(L)	5.0e-10	0.9	(L)	0.26381	0.543	(N)
37	Z	Grov	9	204	47.8 ± 24.3	44.4 ± 30.7	45.6 ± 35.5	0.89543	0.32636	0.532	(N)	0.36495	0.525	(N)	0.5308	0.495	(N)
37	R_y	Grov	9	204	100.0 ± 0.0	96.7 ± 6.6	96.7 ± 5.9	0.01151	0.00277	0.617	(S)	0.00136	0.633	(S)	0.42238	0.512	(N)
38	all	Grov	9	264	79.6 ± 3.5	80.2 ± 8.7	78.7 ± 10.4	0.71416	0.76384	0.451	(N)	0.34203	0.529	(N)	0.26193	0.547	(N)
38	X	Grov	9	264	100.0 ± 0.0	71.1 ± 25.9	65.6 ± 27.0	1.3e-08	4.7e-08	0.833	(L)	6.2e-09	0.867	(L)	0.19826	0.559	(N)
38	Z	Grov	9	264	3.3 ± 10.2	35.6 ± 27.6	33.3 ± 32.8	2.4e-06	1.0	0.168	(L)	0.99999	0.233	(L)	0.33992	0.53	(N)
38	R_y	Grov	9	264	98.1 ± 4.2	98.1 ± 4.2	98.1 ± 5.1	0.94367	0.50457	0.5	(N)	0.62184	0.486	(N)	0.62184	0.486	(N)
39	all	Grov	9	324	78.7 ± 4.1	78.2 ± 9.1	79.8 ± 10.4	0.84899	0.40005	0.518	(N)	0.64389	0.474	(N)	0.70659	0.461	(N)
39	X	Grov	9	324	100.0 ± 0.0	71.1 ± 24.3	77.8 ± 23.7	4.1e-07	4.9e-08	0.833	(L)	2.3e-06	0.767	(L)	0.86397	0.424	(S)
39	Z	Grov	9	324	2.2 ± 8.5	28.9 ± 32.4	33.3 ± 33.9	2.8e-05	0.99997	0.258	(L)	1.0	0.223	(L)	0.70046	0.463	(N)
39	R_y	Grov	9	324	97.0 ± 5.8	97.0 ± 7.1	95.9 ± 8.0	0.81337	0.61761	0.484	(N)	0.36227	0.521	(N)	0.26704	0.535	(N)
40	all	Grov	9	384	78.4 ± 3.4	78.4 ± 7.6	80.2 ± 8.7	0.65679	0.41465	0.516	(N)	0.8102	0.441	(N)	0.76833	0.447	(N)
40	X	Grov	9	384	100.0 ± 0.0	66.7 ± 24.8	63.3 ± 32.0	4.6e-09	1.7e-09	0.883	(L)	2.0e-08	0.85	(L)	0.40869	0.517	(N)
40	Z	Grov	9	384	0.0 ± 0.0	32.2 ± 25.5	44.4 ± 32.0	2.9e-09	1.0	0.15	(L)	1.0	0.117	(L)	0.93566	0.392	(S)
40	R_y	Grov	9	384	97.4 ± 5.6	97.8 ± 5.4	97.8 ± 4.5	0.94401	0.62924	0.484	(N)	0.52971	0.497	(N)	0.40005	0.513	(N)
41	all	Grov	9	444	77.6 ± 4.1	79.6 ± 7.6	80.4 ± 8.0	0.32811	0.80231	0.441	(N)	0.94304	0.389	(S)	0.69265	0.464	(N)
41	X	Grov	9	444	100.0 ± 0.0	70.0 ± 26.8	81.1 ± 22.6	1.2e-06	1.5e-07	0.817	(L)	1.3e-05	0.733	(M)	0.95034	0.386	(S)
41	Z	Grov	9	444	1.1 ± 6.1	36.7 ± 23.7	30.0 ± 25.3	1.0e-08	1.0	0.112	(L)	1.0	0.179	(L)	0.14829	0.573	(N)
41	R_y	Grov	9	444	95.6 ± 6.3	97.0 ± 5.0	97.0 ± 5.0	0.57362	0.81723	0.446	(N)	0.81723	0.446	(N)	0.50385	0.5	(N)

Table 15. Mutation scores for the **Grov** program category. Table 3/3.

								DGR	DG			DR			GR		
ID	Mutant Type	**Category**	**#Qubits**	**Depth**	**Default [%]**	**Greedy [%]**	**Random [%]**	**p-value**	**p-value**	$\hat{A}_{12}$	**Magnitude**	**p-value**	$\hat{A}_{12}$	**Magnitude**	**p-value**	$\hat{A}_{12}$	**Magnitude**
42	all	Grov	9	504	79.3 ± 2.7	78.0 ± 9.8	76.4 ± 9.1	0.1657	0.20394	0.558	(N)	0.01493	0.649	(S)	0.25439	0.549	(N)
42	X	Grov	9	504	100.0 ± 0.0	57.8 ± 31.5	63.3 ± 33.2	1.9e-08	2.3e-09	0.883	(L)	1.5e-07	0.817	(L)	0.74449	0.453	(N)
42	Z	Grov	9	504	1.1 ± 6.1	35.6 ± 26.2	26.7 ± 25.4	6.6e-08	1.0	0.144	(L)	1.0	0.198	(L)	0.07539	0.601	(S)
42	R_y	Grov	9	504	98.5 ± 3.8	98.9 ± 3.4	97.4 ± 4.8	0.33709	0.65986	0.483	(N)	0.16317	0.55	(N)	0.08651	0.567	(N)
43	all	Grov	9	564	79.1 ± 2.3	78.2 ± 9.6	77.3 ± 10.4	0.9065	0.62798	0.478	(N)	0.31667	0.533	(N)	0.40069	0.519	(N)
43	X	Grov	9	564	100.0 ± 0.0	58.9 ± 28.6	56.7 ± 27.9	3.0e-10	2.2e-09	0.883	(L)	2.2e-10	0.917	(L)	0.42527	0.514	(N)
43	Z	Grov	9	564	0.0 ± 0.0	43.3 ± 29.2	38.9 ± 34.0	2.4e-09	1.0	0.083	(L)	1.0	0.167	(L)	0.28861	0.541	(N)
43	R_y	Grov	9	564	98.5 ± 3.8	96.3 ± 6.7	97.0 ± 6.5	0.4013	0.08848	0.571	(N)	0.22209	0.538	(N)	0.71599	0.469	(N)
44	all	Grov	9	624	79.3 ± 2.7	82.4 ± 9.7	82.4 ± 9.3	0.19219	0.91553	0.407	(S)	0.97164	0.376	(S)	0.54249	0.493	(N)
44	X	Grov	9	624	100.0 ± 0.0	62.2 ± 28.7	73.3 ± 26.8	5.2e-08	6.7e-09	0.867	(L)	9.9e-07	0.783	(L)	0.93256	0.394	(S)
44	Z	Grov	9	624	1.1 ± 6.1	58.9 ± 28.6	46.7 ± 29.8	2.5e-11	1.0	0.055	(L)	1.0	0.108	(L)	0.05608	0.611	(S)
44	R_y	Grov	9	624	98.5 ± 3.8	97.0 ± 5.8	97.4 ± 5.6	0.57912	0.15294	0.552	(N)	0.23567	0.536	(N)	0.62154	0.484	(N)
45	all	Grov	9	684	68.7 ± 6.6	74.9 ± 8.5	77.8 ± 9.5	1.5e-04	0.99842	0.285	(M)	0.99997	0.206	(L)	0.88864	0.412	(S)
45	X	Grov	9	684	45.6 ± 32.1	63.3 ± 23.7	54.4 ± 25.5	0.04951	0.99072	0.334	(M)	0.88929	0.414	(S)	0.07917	0.596	(S)
45	Z	Grov	9	684	1.1 ± 6.1	27.8 ± 29.1	47.8 ± 31.2	2.6e-09	1.0	0.214	(L)	1.0	0.092	(L)	0.99489	0.317	(M)
45	R_y	Grov	9	684	98.9 ± 3.4	94.4 ± 7.6	95.6 ± 6.9	0.02118	0.00325	0.655	(S)	0.01326	0.62	(S)	0.7199	0.463	(N)

Table 16. Mutation scores for the **Qwalk** program category. Table 1/2.

								DGR	DG			DR			GR		
ID	Mutant Type	Category	#Qubits	Depth	Default [%]	Greedy [%]	Random [%]	p-value	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude
0	all	Qwalk	3	14	26.7 ± 10.1	72.0 ± 7.9	71.8 ± 9.5	7.9e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.45469	0.509	(N)
0	X	Qwalk	3	14	32.2 ± 28.3	71.1 ± 25.9	61.1 ± 26.4	6.8e-06	1.0	0.175	(L)	0.99978	0.25	(L)	0.0608	0.608	(S)
0	Z	Qwalk	3	14	3.3 ± 10.2	28.9 ± 21.0	33.3 ± 29.0	4.8e-07	1.0	0.177	(L)	1.0	0.188	(L)	0.65521	0.473	(N)
0	R_y	Qwalk	3	14	32.6 ± 12.4	86.7 ± 10.7	88.1 ± 10.5	4.4e-14	1.0	0.001	(L)	1.0	0.001	(L)	0.71102	0.461	(N)
1	all	Qwalk	3	21	26.4 ± 9.5	68.0 ± 10.1	67.6 ± 10.2	1.1e-13	1.0	0.001	(L)	1.0	0.004	(L)	0.45475	0.509	(N)
1	X	Qwalk	3	21	55.6 ± 29.5	55.6 ± 29.5	55.6 ± 29.5	1.0	0.50312	0.5	(N)	0.50312	0.5	(N)	0.50312	0.5	(N)
1	Z	Qwalk	3	21	1.1 ± 6.1	35.6 ± 23.0	35.6 ± 23.0	7.7e-10	1.0	0.112	(L)	1.0	0.112	(L)	0.50325	0.5	(N)
1	R_y	Qwalk	3	21	25.2 ± 14.0	83.0 ± 13.9	82.2 ± 12.6	9.1e-14	1.0	0.001	(L)	1.0	0.004	(L)	0.4213	0.515	(N)
2	all	Qwalk	3	28	40.7 ± 7.7	70.0 ± 5.7	67.1 ± 7.0	4.5e-14	1.0	0.0	(L)	1.0	0.008	(L)	0.06784	0.607	(S)
2	X	Qwalk	3	28	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
2	Z	Qwalk	3	28	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
2	R_y	Qwalk	3	28	34.4 ± 12.8	83.3 ± 9.6	78.5 ± 11.6	4.5e-14	1.0	0.0	(L)	1.0	0.008	(L)	0.06784	0.607	(S)
3	all	Qwalk	3	35	53.8 ± 8.2	72.9 ± 5.8	73.3 ± 5.3	7.2e-13	1.0	0.03	(L)	1.0	0.024	(L)	0.6779	0.468	(N)
3	X	Qwalk	3	35	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
3	Z	Qwalk	3	35	3.3 ± 10.2	2.2 ± 8.5	0.0 ± 0.0	0.23087	0.32717	0.517	(N)	0.0407	0.55	(N)	0.08037	0.533	(N)
3	R_y	Qwalk	3	35	55.2 ± 14.4	87.4 ± 9.1	88.9 ± 8.8	7.6e-13	1.0	0.032	(L)	1.0	0.024	(L)	0.75508	0.452	(N)
4	all	Qwalk	3	42	25.8 ± 10.8	72.0 ± 9.7	73.3 ± 10.5	7.8e-14	1.0	0.0	(L)	1.0	0.001	(L)	0.68371	0.466	(N)
4	X	Qwalk	3	42	28.9 ± 30.0	64.4 ± 28.9	64.4 ± 26.2	8.5e-06	0.99998	0.204	(L)	0.99999	0.194	(L)	0.45877	0.508	(N)
4	Z	Qwalk	3	42	1.1 ± 6.1	24.4 ± 27.6	42.2 ± 21.3	1.4e-09	0.99998	0.263	(L)	1.0	0.061	(L)	0.996	0.313	(M)
4	R_y	Qwalk	3	42	33.0 ± 16.1	90.4 ± 10.4	86.7 ± 12.9	4.5e-14	1.0	0.0	(L)	1.0	0.002	(L)	0.1448	0.576	(S)
5	all	Qwalk	3	49	29.6 ± 10.3	66.7 ± 9.1	67.3 ± 9.2	1.1e-13	1.0	0.006	(L)	1.0	0.001	(L)	0.58716	0.484	(N)
5	X	Qwalk	3	49	65.6 ± 32.1	63.3 ± 32.0	63.3 ± 32.0	0.93986	0.38341	0.522	(N)	0.38341	0.522	(N)	0.50311	0.5	(N)
5	Z	Qwalk	3	49	2.2 ± 8.5	27.8 ± 24.9	27.8 ± 24.9	9.7e-07	1.0	0.196	(L)	1.0	0.196	(L)	0.50328	0.5	(N)
5	R_y	Qwalk	3	49	26.7 ± 11.1	80.7 ± 10.9	81.9 ± 9.9	4.0e-14	1.0	0.001	(L)	1.0	0.001	(L)	0.63571	0.476	(N)
6	all	Qwalk	3	56	39.3 ± 9.2	68.7 ± 9.5	68.2 ± 9.2	9.0e-13	1.0	0.023	(L)	1.0	0.02	(L)	0.42155	0.515	(N)
6	X	Qwalk	3	56	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
6	Z	Qwalk	3	56	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
6	R_y	Qwalk	3	56	32.2 ± 15.3	81.1 ± 15.8	80.4 ± 15.4	9.0e-13	1.0	0.023	(L)	1.0	0.02	(L)	0.42155	0.515	(N)
7	all	Qwalk	3	63	53.3 ± 7.0	73.1 ± 7.3	74.7 ± 5.4	7.0e-13	1.0	0.043	(L)	1.0	0.011	(L)	0.73839	0.456	(N)
7	X	Qwalk	3	63	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
7	Z	Qwalk	3	63	3.3 ± 10.2	1.1 ± 6.1	1.1 ± 6.1	0.43273	0.15641	0.533	(N)	0.15641	0.533	(N)	0.50948	0.5	(N)
7	R_y	Qwalk	3	63	54.4 ± 11.4	88.1 ± 12.4	90.7 ± 9.3	6.6e-13	1.0	0.04	(L)	1.0	0.011	(L)	0.73636	0.456	(N)
8	all	Qwalk	3	70	26.9 ± 9.2	73.1 ± 9.8	72.7 ± 10.1	9.1e-14	1.0	0.001	(L)	1.0	0.001	(L)	0.40762	0.518	(N)
8	X	Qwalk	3	70	33.3 ± 26.3	71.1 ± 27.3	70.0 ± 26.8	1.2e-06	1.0	0.177	(L)	1.0	0.179	(L)	0.43436	0.512	(N)
8	Z	Qwalk	3	70	0.0 ± 0.0	33.3 ± 29.0	34.4 ± 29.7	8.3e-08	1.0	0.167	(L)	1.0	0.167	(L)	0.562	0.489	(N)
8	R_y	Qwalk	3	70	33.7 ± 10.7	87.0 ± 11.3	86.3 ± 11.6	5.2e-14	1.0	0.001	(L)	1.0	0.001	(L)	0.41419	0.516	(N)
9	all	Qwalk	3	77	31.6 ± 14.0	69.6 ± 10.7	69.3 ± 11.2	7.4e-13	1.0	0.019	(L)	1.0	0.019	(L)	0.49395	0.502	(N)
9	X	Qwalk	3	77	60.0 ± 30.8	60.0 ± 30.8	60.0 ± 30.8	1.0	0.50312	0.5	(N)	0.50312	0.5	(N)	0.50312	0.5	(N)
9	Z	Qwalk	3	77	0.0 ± 0.0	30.0 ± 25.3	30.0 ± 25.3	7.0e-08	1.0	0.167	(L)	1.0	0.167	(L)	0.50316	0.5	(N)
9	R_y	Qwalk	3	77	32.6 ± 18.7	85.9 ± 11.3	85.6 ± 10.6	9.2e-14	1.0	0.006	(L)	1.0	0.002	(L)	0.38181	0.522	(N)
10	all	Qwalk	3	84	37.8 ± 9.0	67.8 ± 7.8	68.7 ± 7.5	1.2e-13	1.0	0.008	(L)	1.0	0.005	(L)	0.68915	0.465	(N)
10	X	Qwalk	3	84	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
10	Z	Qwalk	3	84	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
10	R_y	Qwalk	3	84	29.6 ± 15.0	79.6 ± 13.1	81.1 ± 12.4	1.2e-13	1.0	0.008	(L)	1.0	0.005	(L)	0.68915	0.465	(N)
11	all	Qwalk	3	91	51.1 ± 9.0	72.7 ± 7.3	69.8 ± 8.7	2.1e-11	1.0	0.036	(L)	1.0	0.076	(L)	0.10014	0.594	(S)
11	X	Qwalk	3	91	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
11	Z	Qwalk	3	91	1.1 ± 6.1	1.1 ± 6.1	1.1 ± 6.1	1.0	0.50948	0.5	(N)	0.50948	0.5	(N)	0.50948	0.5	(N)
11	R_y	Qwalk	3	91	51.5 ± 14.7	87.4 ± 11.6	82.6 ± 13.9	1.5e-11	1.0	0.033	(L)	1.0	0.073	(L)	0.09534	0.596	(S)
12	all	Qwalk	3	98	27.3 ± 10.1	72.7 ± 10.1	72.4 ± 10.5	9.1e-14	1.0	0.001	(L)	1.0	0.001	(L)	0.48795	0.503	(N)
12	X	Qwalk	3	98	24.4 ± 24.7	64.4 ± 24.7	62.2 ± 31.2	3.6e-07	1.0	0.138	(L)	0.99999	0.186	(L)	0.40951	0.517	(N)
12	Z	Qwalk	3	98	1.1 ± 6.1	33.3 ± 24.8	33.3 ± 26.3	3.7e-08	1.0	0.146	(L)	1.0	0.162	(L)	0.50316	0.5	(N)
12	R_y	Qwalk	3	98	37.0 ± 15.5	88.5 ± 10.7	88.9 ± 9.7	5.5e-14	1.0	0.006	(L)	1.0	0.001	(L)	0.5095	0.499	(N)
13	all	Qwalk	4	18	62.4 ± 6.2	74.0 ± 6.4	74.2 ± 5.5	1.3e-09	1.0	0.111	(L)	1.0	0.084	(L)	0.48429	0.503	(N)
13	X	Qwalk	4	18	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
13	Z	Qwalk	4	18	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
13	R_y	Qwalk	4	18	70.7 ± 10.3	90.0 ± 10.7	90.4 ± 9.1	1.3e-09	1.0	0.111	(L)	1.0	0.084	(L)	0.48429	0.503	(N)
14	all	Qwalk	4	27	65.3 ± 7.1	74.7 ± 10.1	73.6 ± 10.0	9.8e-05	0.99995	0.213	(L)	0.99972	0.248	(L)	0.22677	0.556	(N)
14	X	Qwalk	4	27	100.0 ± 0.0	77.8 ± 22.0	24.4 ± 23.0	2.8e-15	2.8e-07	0.8	(L)	9.8e-13	0.983	(L)	8.5e-10	0.938	(L)
14	Z	Qwalk	4	27	1.1 ± 6.1	31.1 ± 27.6	82.2 ± 24.3	8.3e-15	1.0	0.179	(L)	1.0	0.002	(L)	1.0	0.106	(L)
14	R_y	Qwalk	4	27	75.2 ± 12.3	88.1 ± 13.7	87.0 ± 13.1	1.2e-04	0.99993	0.222	(L)	0.99976	0.247	(L)	0.32491	0.533	(N)
15	all	Qwalk	4	36	72.4 ± 5.5	72.0 ± 8.6	71.3 ± 12.4	0.82929	0.37025	0.524	(N)	0.28331	0.542	(N)	0.37025	0.525	(N)
15	X	Qwalk	4	36	100.0 ± 0.0	42.2 ± 31.5	34.4 ± 32.1	1.2e-12	2.2e-11	0.95	(L)	6.0e-12	0.967	(L)	0.17064	0.569	(N)
15	Z	Qwalk	4	36	3.3 ± 10.2	47.8 ± 22.6	51.1 ± 32.4	6.1e-11	1.0	0.047	(L)	1.0	0.107	(L)	0.71817	0.46	(N)
15	R_y	Qwalk	4	36	86.3 ± 9.1	90.0 ± 9.8	90.4 ± 10.8	0.18276	0.93872	0.391	(S)	0.94961	0.383	(S)	0.6029	0.482	(N)
16	all	Qwalk	4	45	65.8 ± 7.2	74.9 ± 6.9	73.8 ± 7.6	1.6e-05	0.99999	0.186	(L)	0.9999	0.229	(L)	0.25893	0.547	(N)
16	X	Qwalk	4	45	100.0 ± 0.0	76.7 ± 23.4	76.7 ± 23.4	2.3e-06	9.1e-07	0.783	(L)	9.1e-07	0.783	(L)	0.50323	0.5	(N)
16	Z	Qwalk	4	45	4.4 ± 11.5	20.0 ± 18.8	18.9 ± 18.9	7.7e-04	0.99978	0.281	(M)	0.9995	0.298	(M)	0.40683	0.516	(N)
16	R_y	Qwalk	4	45	74.8 ± 11.3	92.6 ± 7.3	91.1 ± 8.9	1.5e-08	1.0	0.109	(L)	1.0	0.145	(L)	0.29559	0.538	(N)
17	all	Qwalk	4	54	71.3 ± 5.8	72.4 ± 12.1	73.6 ± 11.9	0.17635	0.9175	0.399	(S)	0.9618	0.371	(S)	0.67259	0.468	(N)
17	X	Qwalk	4	54	100.0 ± 0.0	56.7 ± 31.7	56.7 ± 31.7	3.3e-10	7.3e-10	0.9	(L)	7.3e-10	0.9	(L)	0.50312	0.5	(N)
17	Z	Qwalk	4	54	0.0 ± 0.0	45.6 ± 27.0	46.7 ± 28.5	5.8e-11	1.0	0.083	(L)	1.0	0.083	(L)	0.55053	0.492	(N)
17	R_y	Qwalk	4	54	85.6 ± 9.7	86.7 ± 11.8	88.1 ± 11.3	0.48357	0.76993	0.448	(N)	0.88581	0.414	(S)	0.67706	0.468	(N)
18	all	Qwalk	4	63	65.6 ± 6.6	72.9 ± 8.6	74.2 ± 8.9	1.7e-04	0.99953	0.261	(L)	0.99994	0.218	(L)	0.71839	0.458	(N)
18	X	Qwalk	4	63	100.0 ± 0.0	78.9 ± 22.3	74.4 ± 27.2	7.1e-06	2.2e-06	0.767	(L)	2.5e-06	0.767	(L)	0.30618	0.536	(N)
18	Z	Qwalk	4	63	0.0 ± 0.0	22.2 ± 26.7	22.2 ± 26.7	2.1e-05	0.99999	0.25	(L)	0.99999	0.25	(L)	0.50325	0.5	(N)
18	R_y	Qwalk	4	63	75.9 ± 11.0	87.8 ± 9.8	91.5 ± 8.1	9.0e-07	0.99993	0.226	(L)	1.0	0.139	(L)	0.9312	0.396	(S)
19	all	Qwalk	4	72	72.4 ± 5.7	73.3 ± 11.1	77.8 ± 9.2	0.03995	0.49388	0.502	(N)	0.99418	0.317	(M)	0.9685	0.363	(S)
19	X	Qwalk	4	72	100.0 ± 0.0	43.3 ± 29.2	60.0 ± 25.4	1.4e-12	5.7e-12	0.967	(L)	1.9e-10	0.917	(L)	0.9861	0.346	(S)
19	Z	Qwalk	4	72	0.0 ± 0.0	52.2 ± 28.6	54.4 ± 27.0	4.3e-13	1.0	0.033	(L)	1.0	0.033	(L)	0.67096	0.469	(N)
19	R_y	Qwalk	4	72	87.4 ± 9.6	90.4 ± 11.9	91.5 ± 11.2	0.14332	0.92321	0.399	(S)	0.97254	0.364	(S)	0.62586	0.478	(N)

Table 17. Mutation scores for the **Qwalk** program category. Table 2/2.

								DGR	DG			DR			GR		
ID	Mutant Type	Category	#Qubits	Depth	Default [%]	Greedy [%]	Random [%]	p-value	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude
20	all	Qwalk	4	81	64.9 ± 6.8	74.9 ± 9.5	75.6 ± 8.3	4.1e-06	0.99997	0.204	(L)	1.0	0.163	(L)	0.50607	0.499	(N)
20	X	Qwalk	4	81	100.0 ± 0.0	76.7 ± 26.5	76.7 ± 26.5	7.3e-06	2.3e-06	0.767	(L)	2.3e-06	0.767	(L)	0.50323	0.5	(N)
20	Z	Qwalk	4	81	2.2 ± 8.5	31.1 ± 21.3	31.1 ± 21.3	1.2e-08	1.0	0.144	(L)	1.0	0.144	(L)	0.50337	0.5	(N)
20	R_y	Qwalk	4	81	74.1 ± 10.2	88.9 ± 7.7	90.0 ± 7.9	8.5e-09	1.0	0.131	(L)	1.0	0.122	(L)	0.68437	0.468	(N)
21	all	Qwalk	4	90	61.1 ± 11.5	76.0 ± 8.3	73.8 ± 10.8	6.6e-07	1.0	0.138	(L)	0.99999	0.192	(L)	0.22007	0.556	(N)
21	X	Qwalk	4	90	82.2 ± 21.0	82.2 ± 21.0	82.2 ± 21.0	1.0	0.50333	0.5	(N)	0.50333	0.5	(N)	0.50333	0.5	(N)
21	Z	Qwalk	4	90	1.1 ± 6.1	24.4 ± 26.2	24.4 ± 26.2	9.9e-06	1.0	0.231	(L)	1.0	0.231	(L)	0.50322	0.5	(N)
21	R_y	Qwalk	4	90	74.1 ± 17.3	91.1 ± 11.1	87.4 ± 13.0	1.7e-04	0.99996	0.214	(L)	0.99879	0.279	(M)	0.13083	0.58	(S)
22	all	Qwalk	4	99	54.0 ± 7.7	68.9 ± 9.8	69.1 ± 10.6	3.1e-08	1.0	0.122	(L)	1.0	0.127	(L)	0.49397	0.502	(N)
22	X	Qwalk	4	99	14.4 ± 22.6	36.7 ± 33.2	34.4 ± 29.7	0.00664	0.99752	0.306	(M)	0.99717	0.309	(M)	0.44138	0.511	(N)
22	Z	Qwalk	4	99	3.3 ± 10.2	52.2 ± 24.3	51.1 ± 25.9	1.2e-11	1.0	0.055	(L)	1.0	0.072	(L)	0.46125	0.507	(N)
22	R_y	Qwalk	4	99	84.1 ± 10.0	85.2 ± 12.5	86.7 ± 10.3	0.6206	0.74285	0.454	(N)	0.83652	0.432	(N)	0.61333	0.48	(N)
23	all	Qwalk	4	108	54.2 ± 10.6	72.9 ± 9.6	70.2 ± 10.2	7.5e-09	1.0	0.093	(L)	1.0	0.13	(L)	0.21226	0.559	(N)
23	X	Qwalk	4	108	55.6 ± 22.0	81.1 ± 20.9	74.4 ± 24.3	1.8e-04	0.99997	0.222	(L)	0.99827	0.298	(M)	0.14893	0.572	(N)
23	Z	Qwalk	4	108	0.0 ± 0.0	26.7 ± 26.8	22.2 ± 22.0	1.2e-06	1.0	0.2	(L)	1.0	0.217	(L)	0.30517	0.536	(N)
23	R_y	Qwalk	4	108	71.9 ± 14.5	85.6 ± 12.1	84.8 ± 12.5	5.0e-04	0.99971	0.248	(L)	0.99951	0.259	(L)	0.43614	0.512	(N)
24	all	Qwalk	4	117	54.9 ± 10.2	73.3 ± 9.3	71.3 ± 10.2	3.8e-09	1.0	0.081	(L)	1.0	0.124	(L)	0.29039	0.541	(N)
24	X	Qwalk	4	117	25.6 ± 32.4	73.3 ± 25.4	73.3 ± 25.4	8.5e-08	1.0	0.143	(L)	1.0	0.143	(L)	0.50317	0.5	(N)
24	Z	Qwalk	4	117	0.0 ± 0.0	22.2 ± 23.7	22.2 ± 23.7	7.2e-06	1.0	0.233	(L)	1.0	0.233	(L)	0.50323	0.5	(N)
24	R_y	Qwalk	4	117	83.0 ± 10.4	90.4 ± 9.6	87.0 ± 12.4	0.02033	0.99751	0.302	(M)	0.95595	0.38	(S)	0.16056	0.571	(N)
25	all	Qwalk	4	126	61.1 ± 7.2	75.6 ± 7.9	73.6 ± 7.5	1.6e-09	1.0	0.089	(L)	1.0	0.117	(L)	0.07463	0.602	(S)
25	X	Qwalk	4	126	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
25	Z	Qwalk	4	126	2.2 ± 8.5	2.2 ± 8.5	1.1 ± 6.1	0.81106	0.50682	0.5	(N)	0.28508	0.517	(N)	0.28508	0.517	(N)
25	R_y	Qwalk	4	126	67.8 ± 11.8	91.9 ± 12.7	88.9 ± 12.0	6.9e-10	1.0	0.083	(L)	1.0	0.107	(L)	0.09215	0.593	(S)
26	all	Qwalk	5	22	52.9 ± 9.6	73.3 ± 6.3	74.7 ± 5.6	2.9e-12	1.0	0.046	(L)	1.0	0.031	(L)	0.79081	0.443	(N)
26	X	Qwalk	5	22	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
26	Z	Qwalk	5	22	2.2 ± 8.5	0.0 ± 0.0	0.0 ± 0.0	0.13229	0.08037	0.533	(N)	0.08037	0.533	(N)	1.0	0.5	(N)
26	R_y	Qwalk	5	22	54.1 ± 14.8	88.9 ± 10.5	91.1 ± 9.4	6.6e-13	1.0	0.031	(L)	1.0	0.019	(L)	0.79081	0.443	(N)
27	all	Qwalk	5	33	52.2 ± 9.3	73.6 ± 5.7	75.6 ± 4.7	2.1e-13	1.0	0.028	(L)	1.0	0.013	(L)	0.88884	0.417	(S)
27	X	Qwalk	5	33	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
27	Z	Qwalk	5	33	0.0 ± 0.0	0.0 ± 0.0	1.1 ± 6.1	0.36788	1.0	0.5	(N)	0.84928	0.483	(N)	0.84928	0.483	(N)
27	R_y	Qwalk	5	33	53.7 ± 15.5	89.3 ± 9.4	92.2 ± 7.2	2.1e-13	1.0	0.028	(L)	1.0	0.013	(L)	0.87527	0.422	(S)
28	all	Qwalk	5	44	44.7 ± 8.6	74.7 ± 6.9	74.2 ± 5.7	4.0e-14	1.0	0.003	(L)	1.0	0.001	(L)	0.27046	0.543	(N)
28	X	Qwalk	5	44	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
28	Z	Qwalk	5	44	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
28	R_y	Qwalk	5	44	41.1 ± 14.3	91.1 ± 11.5	90.4 ± 9.6	4.0e-14	1.0	0.003	(L)	1.0	0.001	(L)	0.27046	0.543	(N)
29	all	Qwalk	5	55	65.3 ± 7.9	74.7 ± 6.6	74.4 ± 6.8	8.7e-06	0.99998	0.198	(L)	0.99998	0.199	(L)	0.43644	0.512	(N)
29	X	Qwalk	5	55	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
29	Z	Qwalk	5	55	1.1 ± 6.1	1.1 ± 6.1	1.1 ± 6.1	1.0	0.50948	0.5	(N)	0.50948	0.5	(N)	0.50948	0.5	(N)
29	R_y	Qwalk	5	55	75.2 ± 12.9	90.7 ± 11.0	90.4 ± 11.2	6.9e-06	0.99999	0.195	(L)	0.99999	0.194	(L)	0.43683	0.512	(N)
30	all	Qwalk	5	66	59.3 ± 6.4	76.7 ± 5.2	75.6 ± 6.4	1.4e-12	1.0	0.027	(L)	1.0	0.046	(L)	0.31546	0.533	(N)
30	X	Qwalk	5	66	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
30	Z	Qwalk	5	66	1.1 ± 6.1	2.2 ± 8.5	1.1 ± 6.1	0.77204	0.72807	0.483	(N)	0.50948	0.5	(N)	0.28508	0.517	(N)
30	R_y	Qwalk	5	66	65.2 ± 10.4	93.7 ± 8.1	92.2 ± 10.2	9.3e-13	1.0	0.026	(L)	1.0	0.042	(L)	0.3834	0.521	(N)
31	all	Qwalk	5	77	48.0 ± 7.5	75.6 ± 9.0	77.8 ± 9.2	1.0e-13	1.0	0.005	(L)	1.0	0.003	(L)	0.80658	0.437	(N)
31	X	Qwalk	5	77	100.0 ± 0.0	57.8 ± 33.8	62.2 ± 31.2	6.0e-09	7.3e-09	0.867	(L)	6.6e-09	0.867	(L)	0.69812	0.463	(N)
31	Z	Qwalk	5	77	1.1 ± 6.1	41.1 ± 24.3	41.1 ± 25.8	2.9e-11	1.0	0.062	(L)	1.0	0.094	(L)	0.57802	0.487	(N)
31	R_y	Qwalk	5	77	46.3 ± 12.4	93.0 ± 9.4	95.2 ± 7.0	1.2e-14	1.0	0.002	(L)	1.0	0.0	(L)	0.78227	0.449	(N)
32	all	Qwalk	5	88	53.6 ± 7.1	74.7 ± 9.0	75.1 ± 9.4	1.7e-12	1.0	0.028	(L)	1.0	0.027	(L)	0.55721	0.49	(N)
32	X	Qwalk	5	88	100.0 ± 0.0	54.4 ± 29.7	55.6 ± 29.5	3.1e-10	7.0e-10	0.9	(L)	7.2e-10	0.9	(L)	0.5716	0.488	(N)
32	Z	Qwalk	5	88	2.2 ± 8.5	38.9 ± 26.4	37.8 ± 27.3	2.5e-08	1.0	0.137	(L)	1.0	0.153	(L)	0.44665	0.51	(N)
32	R_y	Qwalk	5	88	55.2 ± 12.2	93.3 ± 7.5	94.1 ± 7.6	2.6e-14	1.0	0.003	(L)	1.0	0.003	(L)	0.67547	0.47	(N)
33	all	Qwalk	5	99	55.1 ± 8.6	75.3 ± 8.4	77.1 ± 6.9	2.2e-12	1.0	0.047	(L)	1.0	0.02	(L)	0.80694	0.438	(N)
33	X	Qwalk	5	99	100.0 ± 0.0	56.7 ± 21.7	84.4 ± 19.0	3.0e-12	3.5e-12	0.967	(L)	2.9e-05	0.717	(M)	1.0	0.193	(L)
33	Z	Qwalk	5	99	1.1 ± 6.1	34.4 ± 28.3	15.6 ± 21.0	1.8e-07	1.0	0.146	(L)	0.9997	0.316	(M)	0.0029	0.691	(M)
33	R_y	Qwalk	5	99	58.1 ± 13.9	95.2 ± 7.5	95.2 ± 7.0	2.9e-14	1.0	0.012	(L)	1.0	0.011	(L)	0.44403	0.509	(N)
34	all	Qwalk	5	110	57.6 ± 4.5	76.9 ± 8.3	76.9 ± 8.3	7.1e-13	1.0	0.026	(L)	1.0	0.019	(L)	0.55774	0.49	(N)
34	X	Qwalk	5	110	100.0 ± 0.0	60.0 ± 25.4	58.9 ± 25.8	6.0e-12	4.6e-11	0.933	(L)	5.1e-11	0.933	(L)	0.4241	0.513	(N)
34	Z	Qwalk	5	110	2.2 ± 8.5	42.2 ± 26.2	42.2 ± 24.7	5.6e-10	1.0	0.103	(L)	1.0	0.102	(L)	0.54128	0.493	(N)
34	R_y	Qwalk	5	110	61.9 ± 7.0	94.1 ± 7.6	94.4 ± 7.6	1.4e-14	1.0	0.002	(L)	1.0	0.002	(L)	0.5933	0.485	(N)
35	all	Qwalk	5	121	60.9 ± 5.7	76.7 ± 10.9	76.2 ± 9.0	6.7e-09	1.0	0.13	(L)	1.0	0.087	(L)	0.31135	0.537	(N)
35	X	Qwalk	5	121	100.0 ± 0.0	40.0 ± 29.6	36.7 ± 29.5	1.0e-12	5.8e-12	0.967	(L)	1.7e-11	0.95	(L)	0.2847	0.541	(N)
35	Z	Qwalk	5	121	2.2 ± 8.5	70.0 ± 28.2	70.0 ± 25.3	1.8e-13	1.0	0.024	(L)	1.0	0.022	(L)	0.47135	0.506	(N)
35	R_y	Qwalk	5	121	67.4 ± 8.2	91.1 ± 8.5	91.5 ± 9.5	1.9e-12	1.0	0.03	(L)	1.0	0.043	(L)	0.63386	0.477	(N)
36	all	Qwalk	5	132	60.9 ± 5.7	74.7 ± 8.1	74.7 ± 8.3	2.3e-09	1.0	0.097	(L)	1.0	0.1	(L)	0.49392	0.502	(N)
36	X	Qwalk	5	132	100.0 ± 0.0	56.7 ± 27.9	57.8 ± 28.9	1.4e-10	2.2e-10	0.917	(L)	7.2e-10	0.9	(L)	0.55936	0.49	(N)
36	Z	Qwalk	5	132	2.2 ± 8.5	38.9 ± 27.8	38.9 ± 27.8	1.5e-08	1.0	0.138	(L)	1.0	0.138	(L)	0.50313	0.5	(N)
36	R_y	Qwalk	5	132	67.4 ± 9.2	92.6 ± 8.4	92.2 ± 7.2	5.6e-13	1.0	0.035	(L)	1.0	0.023	(L)	0.34127	0.528	(N)
37	all	Qwalk	5	143	61.3 ± 5.4	74.7 ± 6.6	73.6 ± 5.1	2.5e-11	1.0	0.066	(L)	1.0	0.057	(L)	0.22884	0.553	(N)
37	X	Qwalk	5	143	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
37	Z	Qwalk	5	143	2.2 ± 8.5	4.4 ± 11.5	1.1 ± 6.1	0.34222	0.80722	0.467	(N)	0.28508	0.517	(N)	0.0847	0.55	(N)
37	R_y	Qwalk	5	143	68.1 ± 8.1	89.6 ± 10.1	88.9 ± 7.7	9.9e-12	1.0	0.067	(L)	1.0	0.04	(L)	0.2701	0.543	(N)
38	all	Qwalk	5	154	42.7 ± 6.9	75.8 ± 10.4	78.2 ± 8.9	9.4e-14	1.0	0.005	(L)	1.0	0.001	(L)	0.79713	0.439	(N)
38	X	Qwalk	5	154	100.0 ± 0.0	58.9 ± 24.3	60.0 ± 26.8	5.0e-11	5.4e-11	0.933	(L)	6.8e-10	0.9	(L)	0.55101	0.492	(N)
38	Z	Qwalk	5	154	1.1 ± 6.1	38.9 ± 29.1	52.2 ± 27.2	1.1e-11	1.0	0.128	(L)	1.0	0.026	(L)	0.95557	0.382	(S)
38	R_y	Qwalk	5	154	37.4 ± 11.8	93.7 ± 8.1	93.0 ± 9.0	1.8e-14	1.0	0.0	(L)	1.0	0.001	(L)	0.40532	0.517	(N)

Table 18. Mutation scores for the **Var** program category. Table 1/3.

								DGR	DG			DR			GR		
ID	Mutant Type	Category	#Qubits	Depth	Default [%]	Greedy [%]	Random [%]	p-value	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude
0	all	Var	2	6	8.2 ± 6.9	71.8 ± 11.0	72.7 ± 11.3	8.5e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.56575	0.488	(N)
0	X	Var	2	6	1.1 ± 6.1	54.4 ± 29.7	55.6 ± 29.5	2.3e-11	1.0	0.073	(L)	1.0	0.072	(L)	0.57327	0.488	(N)
0	Z	Var	2	6	0.0 ± 0.0	53.3 ± 33.4	53.3 ± 33.4	8.8e-11	1.0	0.083	(L)	1.0	0.083	(L)	0.50308	0.5	(N)
0	R_y	Var	2	6	13.3 ± 10.7	83.7 ± 11.9	84.8 ± 12.2	6.1e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.63776	0.475	(N)
1	all	Var	2	6	12.0 ± 7.3	72.0 ± 12.9	68.9 ± 10.1	6.4e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.15273	0.576	(S)
1	X	Var	2	6	2.2 ± 8.5	57.8 ± 28.9	43.3 ± 29.2	3.5e-11	1.0	0.047	(L)	1.0	0.119	(L)	0.03688	0.628	(S)
1	Z	Var	2	6	4.4 ± 11.5	52.2 ± 34.7	48.9 ± 35.8	1.9e-08	1.0	0.117	(L)	1.0	0.15	(L)	0.36811	0.525	(N)
1	R_y	Var	2	6	17.8 ± 9.9	83.3 ± 13.6	84.1 ± 13.3	6.2e-14	1.0	0.001	(L)	1.0	0.001	(L)	0.59375	0.483	(N)
2	all	Var	2	7	8.9 ± 7.7	71.6 ± 11.2	67.1 ± 11.1	4.7e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.05452	0.618	(S)
2	X	Var	2	7	1.1 ± 6.1	55.6 ± 26.7	44.4 ± 26.7	3.4e-12	1.0	0.024	(L)	1.0	0.092	(L)	0.09286	0.593	(S)
2	Z	Var	2	7	0.0 ± 0.0	57.8 ± 27.6	44.4 ± 26.7	9.4e-13	1.0	0.033	(L)	1.0	0.067	(L)	0.02963	0.633	(S)
2	R_y	Var	2	7	14.4 ± 13.1	81.5 ± 14.4	82.2 ± 12.6	7.0e-14	1.0	0.001	(L)	1.0	0.0	(L)	0.6141	0.479	(N)
3	all	Var	2	7	8.4 ± 6.5	71.6 ± 11.5	69.8 ± 11.6	8.3e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.27645	0.544	(N)
3	X	Var	2	7	1.1 ± 6.1	56.7 ± 27.9	44.4 ± 28.1	7.2e-12	1.0	0.04	(L)	1.0	0.093	(L)	0.05434	0.614	(S)
3	Z	Var	2	7	0.0 ± 0.0	48.9 ± 28.7	53.3 ± 28.5	5.3e-12	1.0	0.05	(L)	1.0	0.067	(L)	0.80456	0.44	(N)
3	R_y	Var	2	7	13.7 ± 11.2	84.1 ± 14.2	83.7 ± 11.6	6.6e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.37709	0.523	(N)
4	all	Var	3	3	48.4 ± 11.1	68.4 ± 9.4	68.0 ± 10.8	2.2e-09	1.0	0.083	(L)	1.0	0.107	(L)	0.47273	0.506	(N)
4	X	Var	3	3	32.2 ± 27.0	31.1 ± 26.2	31.1 ± 26.2	0.98354	0.44063	0.511	(N)	0.44063	0.511	(N)	0.50314	0.5	(N)
4	Z	Var	3	3	3.3 ± 10.2	62.2 ± 25.9	62.2 ± 25.9	4.8e-13	1.0	0.032	(L)	1.0	0.032	(L)	0.5032	0.5	(N)
4	R_y	Var	3	3	68.9 ± 14.1	83.0 ± 9.1	82.2 ± 11.5	3.5e-05	0.99998	0.199	(L)	0.99986	0.235	(L)	0.42213	0.514	(N)
5	all	Var	3	4	48.0 ± 10.0	69.6 ± 9.7	69.6 ± 11.4	1.5e-10	1.0	0.061	(L)	1.0	0.076	(L)	0.47297	0.506	(N)
5	X	Var	3	4	28.9 ± 22.7	28.9 ± 22.7	28.9 ± 22.7	1.0	0.50326	0.5	(N)	0.50326	0.5	(N)	0.50326	0.5	(N)
5	Z	Var	3	4	3.3 ± 13.4	71.1 ± 27.3	71.1 ± 27.3	6.2e-13	1.0	0.033	(L)	1.0	0.033	(L)	0.50317	0.5	(N)
5	R_y	Var	3	4	69.3 ± 13.9	82.6 ± 10.0	82.6 ± 12.9	1.2e-04	0.99993	0.225	(L)	0.99978	0.246	(L)	0.54641	0.492	(N)
6	all	Var	3	3	48.9 ± 9.0	67.8 ± 12.5	65.1 ± 13.1	8.2e-08	1.0	0.116	(L)	1.0	0.156	(L)	0.20922	0.561	(N)
6	X	Var	3	3	28.9 ± 28.7	28.9 ± 28.7	28.9 ± 28.7	1.0	0.50316	0.5	(N)	0.50316	0.5	(N)	0.50316	0.5	(N)
6	Z	Var	3	3	1.1 ± 6.1	67.8 ± 27.0	67.8 ± 27.0	1.2e-13	1.0	0.021	(L)	1.0	0.021	(L)	0.50317	0.5	(N)
6	R_y	Var	3	3	71.5 ± 10.4	80.7 ± 14.0	76.3 ± 12.6	0.02419	0.99496	0.314	(M)	0.96834	0.368	(S)	0.13071	0.582	(S)
7	all	Var	3	4	49.8 ± 9.5	70.2 ± 9.5	70.4 ± 9.2	6.4e-11	1.0	0.059	(L)	1.0	0.062	(L)	0.58698	0.484	(N)
7	X	Var	3	4	35.6 ± 24.7	35.6 ± 24.7	35.6 ± 24.7	1.0	0.50329	0.5	(N)	0.50329	0.5	(N)	0.50329	0.5	(N)
7	Z	Var	3	4	0.0 ± 0.0	71.1 ± 22.7	71.1 ± 22.7	6.6e-15	1.0	0.0	(L)	1.0	0.0	(L)	0.50326	0.5	(N)
7	R_y	Var	3	4	71.1 ± 13.9	81.5 ± 13.5	81.9 ± 13.5	0.00205	0.99747	0.296	(M)	0.99945	0.263	(M)	0.62952	0.477	(N)
8	all	Var	3	4	32.0 ± 7.3	73.1 ± 10.7	71.1 ± 10.0	8.2e-14	1.0	0.0	(L)	1.0	0.001	(L)	0.30135	0.539	(N)
8	X	Var	3	4	1.1 ± 6.1	37.8 ± 25.9	36.7 ± 23.7	1.2e-10	1.0	0.096	(L)	1.0	0.096	(L)	0.47989	0.504	(N)
8	Z	Var	3	4	1.1 ± 6.1	64.4 ± 30.2	64.4 ± 30.2	2.2e-13	1.0	0.023	(L)	1.0	0.023	(L)	0.50311	0.5	(N)
8	R_y	Var	3	4	52.6 ± 11.6	87.8 ± 10.7	84.8 ± 11.8	1.3e-12	1.0	0.02	(L)	1.0	0.039	(L)	0.19769	0.562	(N)
9	all	Var	3	4	31.8 ± 7.6	71.6 ± 9.7	72.0 ± 10.6	8.9e-14	1.0	0.001	(L)	1.0	0.001	(L)	0.56294	0.489	(N)
9	X	Var	3	4	1.1 ± 6.1	32.2 ± 23.9	33.3 ± 24.8	1.7e-08	1.0	0.146	(L)	1.0	0.146	(L)	0.57304	0.488	(N)
9	Z	Var	3	4	0.0 ± 0.0	63.3 ± 28.2	63.3 ± 28.2	3.7e-13	1.0	0.033	(L)	1.0	0.033	(L)	0.50319	0.5	(N)
9	R_y	Var	3	4	52.6 ± 12.7	87.4 ± 10.4	87.8 ± 10.7	5.5e-13	1.0	0.022	(L)	1.0	0.022	(L)	0.5682	0.488	(N)
10	all	Var	3	5	28.4 ± 6.8	73.1 ± 8.7	72.9 ± 9.1	7.4e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.47278	0.506	(N)
10	X	Var	3	5	0.0 ± 0.0	31.1 ± 30.2	31.1 ± 30.2	9.5e-07	1.0	0.2	(L)	1.0	0.2	(L)	0.50313	0.5	(N)
10	Z	Var	3	5	0.0 ± 0.0	76.7 ± 26.5	75.6 ± 27.6	8.6e-15	1.0	0.0	(L)	1.0	0.0	(L)	0.45511	0.508	(N)
10	R_y	Var	3	5	47.4 ± 11.3	85.9 ± 10.1	85.9 ± 9.2	8.3e-14	1.0	0.008	(L)	1.0	0.008	(L)	0.51592	0.498	(N)
11	all	Var	3	5	30.4 ± 6.7	72.0 ± 10.6	71.8 ± 10.6	7.6e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.46374	0.507	(N)
11	X	Var	3	5	1.1 ± 6.1	36.7 ± 28.2	35.6 ± 27.6	2.0e-08	1.0	0.144	(L)	1.0	0.145	(L)	0.4376	0.512	(N)
11	Z	Var	3	5	3.3 ± 10.2	60.0 ± 28.2	61.1 ± 27.8	3.6e-12	1.0	0.05	(L)	1.0	0.048	(L)	0.57259	0.488	(N)
11	R_y	Var	3	5	49.3 ± 10.8	87.8 ± 11.1	87.4 ± 13.6	5.7e-13	1.0	0.013	(L)	1.0	0.028	(L)	0.58003	0.486	(N)
12	all	Var	4	69	51.3 ± 11.0	65.8 ± 12.8	66.2 ± 11.2	1.7e-06	0.99999	0.179	(L)	1.0	0.161	(L)	0.49096	0.502	(N)
12	X	Var	4	69	53.3 ± 27.1	53.3 ± 27.1	53.3 ± 27.1	1.0	0.50321	0.5	(N)	0.50321	0.5	(N)	0.50321	0.5	(N)
12	Z	Var	4	69	1.1 ± 6.1	52.2 ± 28.6	52.2 ± 28.6	7.3e-12	1.0	0.058	(L)	1.0	0.058	(L)	0.50314	0.5	(N)
12	R_y	Var	4	69	67.4 ± 14.0	74.4 ± 14.3	75.2 ± 13.9	0.04274	0.98622	0.339	(S)	0.98405	0.343	(S)	0.51523	0.498	(N)
13	all	Var	4	70	37.3 ± 5.4	69.6 ± 7.4	62.4 ± 10.3	3.3e-14	1.0	0.0	(L)	1.0	0.017	(L)	0.00412	0.693	(M)
13	X	Var	4	70	0.0 ± 0.0	0.0 ± 0.0	2.2 ± 8.5	0.13229	1.0	0.5	(N)	0.92649	0.467	(N)	0.92649	0.467	(N)
13	Z	Var	4	70	0.0 ± 0.0	100.0 ± 0.0	72.2 ± 23.3	1.0e-17	1.0	0.0	(L)	1.0	0.0	(L)	4.7e-08	0.833	(L)
13	R_y	Var	4	70	62.2 ± 9.0	82.6 ± 12.3	79.3 ± 14.8	1.0e-07	1.0	0.098	(L)	0.99999	0.192	(L)	0.24234	0.552	(N)
14	all	Var	4	70	38.0 ± 6.3	68.2 ± 7.6	66.0 ± 9.2	1.2e-13	1.0	0.001	(L)	1.0	0.011	(L)	0.22544	0.556	(N)
14	X	Var	4	70	0.0 ± 0.0	0.0 ± 0.0	2.2 ± 8.5	0.13229	1.0	0.5	(N)	0.92649	0.467	(N)	0.92649	0.467	(N)
14	Z	Var	4	70	0.0 ± 0.0	100.0 ± 0.0	76.7 ± 21.7	1.4e-17	1.0	0.0	(L)	1.0	0.0	(L)	3.3e-07	0.8	(L)
14	R_y	Var	4	70	63.3 ± 10.6	80.4 ± 12.6	83.7 ± 13.9	1.6e-07	1.0	0.161	(L)	1.0	0.138	(L)	0.85715	0.423	(S)
15	all	Var	4	70	37.8 ± 6.4	69.3 ± 7.1	64.4 ± 10.1	7.6e-14	1.0	0.0	(L)	1.0	0.016	(L)	0.02842	0.64	(S)
15	X	Var	4	70	3.3 ± 10.2	0.0 ± 0.0	1.1 ± 6.1	0.16348	0.0407	0.55	(N)	0.15641	0.533	(N)	0.84928	0.483	(N)
15	Z	Var	4	70	0.0 ± 0.0	100.0 ± 0.0	76.7 ± 23.4	1.7e-17	1.0	0.0	(L)	1.0	0.0	(L)	9.1e-07	0.783	(L)
15	R_y	Var	4	70	61.9 ± 9.5	82.2 ± 11.9	81.5 ± 13.2	8.6e-09	1.0	0.099	(L)	1.0	0.128	(L)	0.45132	0.509	(N)
16	all	Var	4	11	33.3 ± 8.8	71.6 ± 12.0	71.1 ± 11.9	1.6e-13	1.0	0.005	(L)	1.0	0.004	(L)	0.38491	0.522	(N)
16	X	Var	4	11	21.1 ± 27.0	45.6 ± 29.7	46.7 ± 29.8	8.7e-04	0.99935	0.272	(M)	0.99953	0.264	(M)	0.5713	0.488	(N)
16	Z	Var	4	11	2.2 ± 8.5	50.0 ± 24.4	48.9 ± 25.9	2.2e-11	1.0	0.064	(L)	1.0	0.081	(L)	0.46087	0.507	(N)
16	R_y	Var	4	11	47.8 ± 9.7	87.4 ± 11.2	86.7 ± 10.7	7.2e-14	1.0	0.002	(L)	1.0	0.003	(L)	0.41126	0.517	(N)
17	all	Var	4	11	36.0 ± 8.9	73.1 ± 10.3	73.1 ± 9.5	1.0e-13	1.0	0.001	(L)	1.0	0.005	(L)	0.56955	0.488	(N)
17	X	Var	4	11	24.4 ± 19.4	57.8 ± 30.2	57.8 ± 30.2	5.5e-06	0.99999	0.196	(L)	0.99999	0.196	(L)	0.50312	0.5	(N)
17	Z	Var	4	11	1.1 ± 6.1	46.7 ± 29.8	46.7 ± 29.8	2.2e-10	1.0	0.092	(L)	1.0	0.092	(L)	0.50312	0.5	(N)
17	R_y	Var	4	11	51.5 ± 11.1	87.0 ± 9.7	87.0 ± 7.8	4.5e-14	1.0	0.016	(L)	1.0	0.004	(L)	0.37785	0.521	(N)
18	all	Var	4	12	39.6 ± 7.8	74.7 ± 9.5	76.4 ± 9.2	8.7e-14	1.0	0.002	(L)	1.0	0.002	(L)	0.76874	0.447	(N)
18	X	Var	4	12	41.1 ± 24.3	64.4 ± 23.0	66.7 ± 23.2	1.9e-04	0.9997	0.261	(L)	0.99989	0.242	(L)	0.64915	0.474	(N)
18	Z	Var	4	12	2.2 ± 8.5	44.4 ± 29.5	44.4 ± 29.5	7.1e-09	1.0	0.132	(L)	1.0	0.132	(L)	0.5032	0.5	(N)
18	R_y	Var	4	12	51.5 ± 11.5	88.1 ± 8.7	90.4 ± 8.6	3.7e-14	1.0	0.004	(L)	1.0	0.0	(L)	0.82727	0.434	(N)
19	all	Var	4	12	33.6 ± 7.9	72.0 ± 13.1	70.9 ± 11.1	2.6e-13	1.0	0.013	(L)	1.0	0.008	(L)	0.22098	0.557	(N)
19	X	Var	4	12	20.0 ± 24.1	45.6 ± 29.7	45.6 ± 32.1	0.00101	0.99955	0.264	(M)	0.99917	0.277	(M)	0.4907	0.502	(N)
19	Z	Var	4	12	0.0 ± 0.0	53.3 ± 28.5	53.3 ± 28.5	4.6e-13	1.0	0.033	(L)	1.0	0.033	(L)	0.50315	0.5	(N)
19	R_y	Var	4	12	49.3 ± 11.6	87.0 ± 14.0	85.2 ± 10.7	9.5e-13	1.0	0.032	(L)	1.0	0.021	(L)	0.15599	0.573	(N)
20	all	Var	5	11	59.6 ± 8.7	78.0 ± 10.1	73.8 ± 7.2	9.5e-10	1.0	0.086	(L)	1.0	0.114	(L)	0.01623	0.656	(S)
20	X	Var	5	11	45.6 ± 27.0	90.0 ± 17.8	75.6 ± 24.7	2.8e-08	1.0	0.104	(L)	0.99995	0.223	(L)	0.00692	0.663	(S)
20	Z	Var	5	11	1.1 ± 6.1	25.6 ± 25.8	16.7 ± 21.0	1.8e-05	1.0	0.214	(L)	0.99987	0.299	(M)	0.08566	0.593	(S)
20	R_y	Var	5	11	83.7 ± 11.2	91.5 ± 11.2	92.2 ± 9.3	0.00286	0.9979	0.296	(M)	0.99871	0.285	(M)	0.52256	0.497	(N)

Table 19. Mutation scores for the **Var** program category. Table 2/3.

								DGR	DG			DR			GR		
ID	Mutant Type	Category	#Qubits	Depth	Default [%]	Greedy [%]	Random [%]	p-value	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude
21	all	Var	5	11	56.2 ± 8.9	73.3 ± 9.9	75.8 ± 6.9	3.4e-11	1.0	0.102	(L)	1.0	0.02	(L)	0.76633	0.448	(N)
21	X	Var	5	11	38.9 ± 29.1	76.7 ± 26.5	84.4 ± 19.0	4.1e-08	1.0	0.18	(L)	1.0	0.115	(L)	0.85525	0.429	(N)
21	Z	Var	5	11	0.0 ± 0.0	24.4 ± 26.2	13.3 ± 22.5	2.3e-05	1.0	0.233	(L)	0.99971	0.333	(M)	0.03515	0.621	(S)
21	R_y	Var	5	11	80.7 ± 11.6	88.5 ± 9.4	93.7 ± 7.0	2.1e-05	0.99723	0.302	(M)	1.0	0.182	(L)	0.98697	0.347	(S)
22	all	Var	5	12	57.3 ± 7.3	72.9 ± 10.6	74.4 ± 8.2	1.7e-09	1.0	0.12	(L)	1.0	0.072	(L)	0.76577	0.447	(N)
22	X	Var	5	12	38.9 ± 27.8	73.3 ± 26.8	87.8 ± 18.5	1.3e-08	0.99998	0.206	(L)	1.0	0.09	(L)	0.98546	0.354	(S)
22	Z	Var	5	12	1.1 ± 6.1	23.3 ± 23.4	17.8 ± 16.9	1.3e-05	1.0	0.231	(L)	0.99999	0.25	(L)	0.22047	0.552	(N)
22	R_y	Var	5	12	82.2 ± 9.0	89.3 ± 10.7	88.9 ± 12.0	0.01221	0.99577	0.312	(M)	0.99425	0.319	(M)	0.51246	0.498	(N)
23	all	Var	5	12	57.8 ± 7.3	75.1 ± 9.3	74.7 ± 8.5	1.6e-10	1.0	0.074	(L)	1.0	0.068	(L)	0.5091	0.499	(N)
23	X	Var	5	12	34.4 ± 25.5	76.7 ± 21.7	83.3 ± 21.0	1.1e-09	1.0	0.123	(L)	1.0	0.092	(L)	0.89769	0.415	(S)
23	Z	Var	5	12	1.1 ± 6.1	27.8 ± 24.9	23.3 ± 21.7	1.5e-06	1.0	0.197	(L)	1.0	0.215	(L)	0.25925	0.545	(N)
23	R_y	Var	5	12	84.4 ± 9.0	90.4 ± 9.1	88.9 ± 9.2	0.0373	0.99194	0.33	(M)	0.97455	0.362	(S)	0.28316	0.541	(N)
24	all	Var	6	8	0.7 ± 2.0	74.9 ± 4.5	75.8 ± 4.8	9.9e-15	1.0	0.0	(L)	1.0	0.0	(L)	0.80216	0.442	(N)
24	X	Var	6	8	1.1 ± 6.1	100.0 ± 0.0	100.0 ± 0.0	6.0e-20	1.0	0.0	(L)	1.0	0.0	(L)	1.0	0.5	(N)
24	Z	Var	6	8	0.0 ± 0.0	2.2 ± 8.5	0.0 ± 0.0	0.13229	0.92649	0.467	(N)	1.0	0.5	(N)	0.08037	0.533	(N)
24	R_y	Var	6	8	0.7 ± 2.8	90.7 ± 7.2	93.0 ± 8.0	7.2e-15	1.0	0.0	(L)	1.0	0.0	(L)	0.89835	0.413	(S)
25	all	Var	6	8	1.3 ± 2.7	74.7 ± 7.9	74.0 ± 6.9	2.5e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.38882	0.521	(N)
25	X	Var	6	8	0.0 ± 0.0	85.6 ± 16.8	85.6 ± 16.8	2.8e-15	1.0	0.0	(L)	1.0	0.0	(L)	0.50344	0.5	(N)
25	Z	Var	6	8	1.1 ± 6.1	20.0 ± 22.5	17.8 ± 22.7	1.9e-04	0.99998	0.265	(M)	0.99987	0.298	(M)	0.3305	0.53	(N)
25	R_y	Var	6	8	1.9 ± 4.2	89.3 ± 11.1	88.9 ± 8.8	2.4e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.33087	0.532	(N)
26	all	Var	6	8	0.9 ± 2.3	74.0 ± 5.6	74.2 ± 5.2	1.9e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.52518	0.496	(N)
26	X	Var	6	8	1.1 ± 6.1	100.0 ± 0.0	100.0 ± 0.0	6.0e-20	1.0	0.0	(L)	1.0	0.0	(L)	1.0	0.5	(N)
26	Z	Var	6	8	1.1 ± 6.1	0.0 ± 0.0	1.1 ± 6.1	0.60309	0.16686	0.517	(N)	0.50948	0.5	(N)	0.84928	0.483	(N)
26	R_y	Var	6	8	0.7 ± 2.8	90.0 ± 9.4	90.0 ± 8.4	1.5e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.45282	0.509	(N)
27	all	Var	6	8	2.4 ± 3.7	73.1 ± 5.9	73.3 ± 5.8	3.5e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.51245	0.498	(N)
27	X	Var	6	8	0.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	4.7e-20	1.0	0.0	(L)	1.0	0.0	(L)	1.0	0.5	(N)
27	Z	Var	6	8	1.1 ± 6.1	0.0 ± 0.0	0.0 ± 0.0	0.36788	0.16686	0.517	(N)	0.16686	0.517	(N)	1.0	0.5	(N)
27	R_y	Var	6	8	3.7 ± 6.1	88.5 ± 9.9	88.9 ± 9.7	3.4e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.51245	0.498	(N)
28	all	Var	6	14	1.3 ± 2.7	74.2 ± 10.6	74.7 ± 10.6	4.4e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.5901	0.484	(N)
28	X	Var	6	14	1.1 ± 6.1	77.8 ± 22.0	50.0 ± 17.0	3.0e-16	1.0	0.002	(L)	1.0	0.008	(L)	4.5e-06	0.808	(L)
28	Z	Var	6	14	2.2 ± 8.5	25.6 ± 22.6	61.1 ± 26.4	5.6e-13	1.0	0.212	(L)	1.0	0.013	(L)	1.0	0.178	(L)
28	R_y	Var	6	14	1.1 ± 3.4	89.3 ± 9.0	87.4 ± 11.6	1.4e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.36296	0.525	(N)
29	all	Var	6	14	0.9 ± 2.3	75.3 ± 8.6	74.0 ± 9.2	3.2e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.21	0.559	(N)
29	X	Var	6	14	0.0 ± 0.0	88.9 ± 18.2	90.0 ± 15.5	8.4e-16	1.0	0.0	(L)	1.0	0.0	(L)	0.53697	0.495	(N)
29	Z	Var	6	14	2.2 ± 8.5	18.9 ± 22.6	18.9 ± 24.3	0.00117	0.99978	0.297	(M)	0.99954	0.312	(M)	0.46038	0.507	(N)
29	R_y	Var	6	14	0.7 ± 2.8	89.6 ± 9.2	87.0 ± 9.7	1.0e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.12578	0.581	(S)
30	all	Var	6	14	0.9 ± 2.3	73.8 ± 6.3	74.4 ± 5.6	2.0e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.6383	0.476	(N)
30	X	Var	6	14	0.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	4.7e-20	1.0	0.0	(L)	1.0	0.0	(L)	1.0	0.5	(N)
30	Z	Var	6	14	2.2 ± 8.5	0.0 ± 0.0	1.1 ± 6.1	0.35952	0.08037	0.533	(N)	0.28508	0.517	(N)	0.84928	0.483	(N)
30	R_y	Var	6	14	0.7 ± 2.8	89.6 ± 10.5	90.4 ± 9.1	1.7e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.57781	0.487	(N)
31	all	Var	6	14	0.7 ± 2.0	73.6 ± 9.0	75.1 ± 12.6	3.9e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.66887	0.468	(N)
31	X	Var	6	14	0.0 ± 0.0	81.1 ± 22.6	45.6 ± 35.5	5.6e-14	1.0	0.0	(L)	1.0	0.117	(L)	5.5e-05	0.778	(L)
31	Z	Var	6	14	0.0 ± 0.0	22.2 ± 29.5	60.0 ± 26.8	9.7e-13	0.99999	0.267	(M)	1.0	0.017	(L)	1.0	0.174	(L)
31	R_y	Var	6	14	1.1 ± 3.4	88.1 ± 13.0	90.0 ± 11.1	1.9e-14	1.0	0.0	(L)	1.0	0.0	(L)	0.6783	0.468	(N)
32	all	Var	6	11	62.2 ± 8.6	75.1 ± 4.3	74.7 ± 5.6	5.4e-09	1.0	0.103	(L)	1.0	0.124	(L)	0.48394	0.503	(N)
32	X	Var	6	11	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
32	Z	Var	6	11	1.1 ± 6.1	1.1 ± 6.1	1.1 ± 6.1	1.0	0.50948	0.5	(N)	0.50948	0.5	(N)	0.50948	0.5	(N)
32	R_y	Var	6	11	70.0 ± 14.3	91.5 ± 7.5	90.7 ± 9.7	7.7e-09	1.0	0.106	(L)	1.0	0.126	(L)	0.47457	0.505	(N)
33	all	Var	6	12	62.0 ± 9.3	76.0 ± 4.5	75.8 ± 4.8	4.3e-10	1.0	0.087	(L)	1.0	0.093	(L)	0.45443	0.508	(N)
33	X	Var	6	12	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
33	Z	Var	6	12	2.2 ± 8.5	0.0 ± 0.0	0.0 ± 0.0	0.13229	0.08037	0.533	(N)	0.08037	0.533	(N)	1.0	0.5	(N)
33	R_y	Var	6	12	69.3 ± 15.4	93.3 ± 7.5	93.0 ± 8.0	2.9e-10	1.0	0.083	(L)	1.0	0.089	(L)	0.45443	0.508	(N)
34	all	Var	6	12	62.7 ± 8.9	75.3 ± 7.0	74.4 ± 6.3	7.9e-08	1.0	0.138	(L)	1.0	0.147	(L)	0.22433	0.553	(N)
34	X	Var	6	12	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
34	Z	Var	6	12	0.0 ± 0.0	1.1 ± 6.1	0.0 ± 0.0	0.36788	0.84928	0.483	(N)	1.0	0.5	(N)	0.16686	0.517	(N)
34	R_y	Var	6	12	71.1 ± 14.8	91.9 ± 11.3	90.7 ± 10.6	8.0e-08	1.0	0.139	(L)	1.0	0.147	(L)	0.25517	0.546	(N)
35	all	Var	6	12	62.2 ± 8.5	76.9 ± 4.9	77.1 ± 4.2	2.7e-11	1.0	0.072	(L)	1.0	0.065	(L)	0.50666	0.499	(N)
35	X	Var	6	12	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	id	1.0	0.5	(N)	1.0	0.5	(N)	1.0	0.5	(N)
35	Z	Var	6	12	0.0 ± 0.0	1.1 ± 6.1	1.1 ± 6.1	0.60309	0.84928	0.483	(N)	0.84928	0.483	(N)	0.50948	0.5	(N)
35	R_y	Var	6	12	70.4 ± 14.1	94.4 ± 7.6	94.8 ± 6.3	2.1e-11	1.0	0.072	(L)	1.0	0.065	(L)	0.50679	0.499	(N)
36	all	Var	7	41	62.7 ± 8.9	70.4 ± 12.1	67.3 ± 11.1	0.01179	0.99738	0.294	(M)	0.97914	0.351	(S)	0.11747	0.588	(S)
36	X	Var	7	41	60.0 ± 28.2	60.0 ± 28.2	60.0 ± 28.2	1.0	0.50328	0.5	(N)	0.50328	0.5	(N)	0.50328	0.5	(N)
36	Z	Var	7	41	0.0 ± 0.0	41.1 ± 29.9	16.7 ± 19.1	1.5e-09	1.0	0.1	(L)	0.99999	0.267	(M)	4.2e-04	0.733	(M)
36	R_y	Var	7	41	84.4 ± 11.9	83.7 ± 12.6	86.7 ± 11.1	0.61599	0.44214	0.511	(N)	0.77481	0.446	(N)	0.82703	0.433	(N)
37	all	Var	7	41	70.2 ± 6.2	75.6 ± 6.4	73.3 ± 7.4	0.00992	0.99804	0.293	(M)	0.98356	0.35	(S)	0.16476	0.57	(N)
37	X	Var	7	41	100.0 ± 0.0	92.2 ± 14.3	100.0 ± 0.0	5.5e-04	0.00273	0.617	(S)	1.0	0.5	(N)	0.99748	0.383	(S)
37	Z	Var	7	41	2.2 ± 8.5	20.0 ± 20.7	1.1 ± 6.1	8.0e-07	0.99996	0.264	(M)	0.28508	0.517	(N)	1.1e-05	0.751	(L)
37	R_y	Var	7	41	83.0 ± 10.8	88.5 ± 9.9	88.5 ± 11.8	0.05067	0.97193	0.363	(S)	0.98873	0.339	(S)	0.64105	0.475	(N)
38	all	Var	7	41	69.3 ± 6.5	75.3 ± 7.7	74.9 ± 8.7	0.00419	0.99844	0.287	(M)	0.99722	0.3	(M)	0.5	0.501	(N)
38	X	Var	7	41	100.0 ± 0.0	82.2 ± 21.0	84.4 ± 21.0	1.2e-04	1.3e-05	0.733	(M)	6.8e-05	0.7	(M)	0.6846	0.469	(N)
38	Z	Var	7	41	0.0 ± 0.0	15.6 ± 21.0	20.0 ± 20.7	3.0e-05	0.99994	0.3	(M)	1.0	0.233	(L)	0.82723	0.438	(N)
38	R_y	Var	7	41	82.2 ± 10.8	93.0 ± 8.0	90.0 ± 9.4	3.5e-04	0.99993	0.228	(L)	0.99724	0.301	(M)	0.11254	0.585	(S)
39	all	Var	7	41	60.7 ± 8.6	68.4 ± 10.5	66.9 ± 8.7	0.00379	0.99883	0.277	(M)	0.99577	0.309	(M)	0.21149	0.559	(N)
39	X	Var	7	41	54.4 ± 23.9	53.3 ± 25.7	53.3 ± 25.7	0.99269	0.46147	0.507	(N)	0.46147	0.507	(N)	0.5032	0.5	(N)
39	Z	Var	7	41	0.0 ± 0.0	47.8 ± 24.3	20.0 ± 20.7	3.6e-12	1.0	0.033	(L)	1.0	0.233	(L)	2.0e-05	0.787	(L)
39	R_y	Var	7	41	83.0 ± 10.8	80.4 ± 12.9	87.0 ± 11.0	0.08857	0.27922	0.542	(N)	0.93314	0.393	(S)	0.98498	0.346	(S)
40	all	Var	8	17	65.1 ± 8.5	71.1 ± 9.6	68.2 ± 10.7	0.06203	0.99105	0.327	(M)	0.93107	0.392	(S)	0.229	0.555	(N)
40	X	Var	8	17	44.4 ± 34.3	68.9 ± 31.5	67.8 ± 32.1	0.01147	0.99596	0.309	(M)	0.99392	0.319	(M)	0.45287	0.509	(N)
40	Z	Var	8	17	1.1 ± 6.1	27.8 ± 23.3	14.4 ± 18.9	7.7e-07	1.0	0.165	(L)	0.9997	0.316	(M)	0.00911	0.659	(S)
40	R_y	Var	8	17	93.3 ± 8.0	86.3 ± 12.9	86.3 ± 13.3	0.04393	0.01525	0.653	(S)	0.01432	0.653	(S)	0.52152	0.497	(N)

Table 20. Mutation scores for the **Var** program category. Table 3/3.

								DGR	DG			DR			GR		
ID	Mutant Type	Category	#Qubits	Depth	Default [%]	Greedy [%]	Random [%]	p-value	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude
41	all	Var	8	17	67.6 ± 7.4	72.2 ± 8.6	69.3 ± 10.4	0.0626	0.98901	0.334	(M)	0.94113	0.387	(S)	0.20841	0.559	(N)
41	X	Var	8	17	48.9 ± 33.6	72.2 ± 27.8	58.9 ± 29.9	0.02108	0.99647	0.307	(M)	0.89221	0.412	(S)	0.04686	0.62	(S)
41	Z	Var	8	17	3.3 ± 10.2	23.3 ± 21.7	24.4 ± 21.3	2.4e-05	0.99998	0.245	(L)	0.99999	0.228	(L)	0.59122	0.485	(N)
41	R_y	Var	8	17	95.2 ± 6.3	88.5 ± 10.3	87.8 ± 13.8	0.00976	0.00217	0.696	(M)	0.00821	0.664	(S)	0.61377	0.481	(N)
42	all	Var	8	17	64.0 ± 8.3	75.8 ± 7.7	72.4 ± 11.4	1.7e-05	1.0	0.152	(L)	0.99897	0.273	(M)	0.14701	0.577	(S)
42	X	Var	8	17	44.4 ± 28.1	83.3 ± 22.7	72.2 ± 29.1	3.0e-06	1.0	0.158	(L)	0.99981	0.246	(L)	0.06003	0.607	(S)
42	Z	Var	8	17	0.0 ± 0.0	12.2 ± 20.5	13.3 ± 20.7	0.00262	0.99938	0.35	(S)	0.99971	0.333	(M)	0.60367	0.484	(N)
42	R_y	Var	8	17	91.9 ± 9.2	94.4 ± 8.1	92.2 ± 10.2	0.50921	0.88549	0.419	(S)	0.64511	0.475	(N)	0.24641	0.546	(N)
43	all	Var	8	17	64.7 ± 6.8	73.8 ± 8.9	71.8 ± 8.7	1.4e-04	0.99994	0.219	(L)	0.99965	0.253	(L)	0.25908	0.548	(N)
43	X	Var	8	17	53.3 ± 28.5	71.1 ± 27.3	57.8 ± 26.2	0.03519	0.99201	0.33	(M)	0.70204	0.463	(N)	0.02403	0.64	(S)
43	Z	Var	8	17	0.0 ± 0.0	26.7 ± 25.4	25.6 ± 25.8	3.6e-07	1.0	0.183	(L)	1.0	0.2	(L)	0.41962	0.514	(N)
43	R_y	Var	8	17	90.0 ± 8.4	90.4 ± 8.6	91.9 ± 8.7	0.59339	0.57533	0.487	(N)	0.83687	0.432	(N)	0.7804	0.447	(N)

Table 21. Mutation scores for the **Gs** program category.

								DGR	DG			DR			GR		
ID	Mutant Type	Category	#Qubits	Depth	Default [%]	Greedy [%]	Random [%]	p-value	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude	p-value	$\hat{A}_{12}$	Magnitude
0	all	Gs	3	5	44.9 ± 10.3	67.3 ± 12.8	68.9 ± 13.3	8.5e-10	1.0	0.089	(L)	1.0	0.081	(L)	0.67941	0.466	(N)
0	X	Gs	3	5	67.8 ± 32.1	67.8 ± 32.1	67.8 ± 32.1	1.0	0.50315	0.5	(N)	0.50315	0.5	(N)	0.50315	0.5	(N)
0	Z	Gs	3	5	2.2 ± 8.5	30.0 ± 26.8	30.0 ± 26.8	3.4e-06	1.0	0.208	(L)	1.0	0.208	(L)	0.50314	0.5	(N)
0	R_y	Gs	3	5	51.5 ± 13.8	79.6 ± 14.3	82.2 ± 15.0	4.9e-10	1.0	0.087	(L)	1.0	0.077	(L)	0.7833	0.443	(N)
1	all	Gs	4	6	31.6 ± 9.7	72.7 ± 8.8	70.9 ± 9.2	9.6e-14	1.0	0.001	(L)	1.0	0.008	(L)	0.21793	0.557	(N)
1	X	Gs	4	6	57.8 ± 27.6	78.9 ± 20.5	78.9 ± 28.3	0.00154	0.99888	0.288	(M)	0.99905	0.282	(M)	0.70092	0.465	(N)
1	Z	Gs	4	6	2.2 ± 8.5	24.4 ± 23.0	20.0 ± 24.1	3.8e-05	1.0	0.214	(L)	0.99979	0.296	(M)	0.1953	0.559	(N)
1	R_y	Gs	4	6	32.6 ± 13.0	86.7 ± 9.9	85.2 ± 13.2	8.6e-14	1.0	0.002	(L)	1.0	0.016	(L)	0.35342	0.527	(N)
2	all	Gs	5	7	40.7 ± 12.9	73.3 ± 11.9	68.0 ± 13.7	1.1e-11	1.0	0.025	(L)	1.0	0.071	(L)	0.07	0.61	(S)
2	X	Gs	5	7	47.8 ± 31.2	63.3 ± 28.2	47.8 ± 31.2	0.08678	0.97253	0.363	(S)	0.5031	0.5	(N)	0.02846	0.637	(S)
2	Z	Gs	5	7	1.1 ± 6.1	41.1 ± 29.9	40.0 ± 30.8	9.7e-09	1.0	0.127	(L)	1.0	0.143	(L)	0.44744	0.51	(N)
2	R_y	Gs	5	7	51.5 ± 13.8	87.4 ± 11.2	84.1 ± 12.6	3.2e-12	1.0	0.024	(L)	1.0	0.053	(L)	0.18063	0.566	(N)
3	all	Gs	6	8	43.1 ± 7.8	75.8 ± 8.5	73.6 ± 8.1	6.4e-14	1.0	0.0	(L)	1.0	0.002	(L)	0.20035	0.562	(N)
3	X	Gs	6	8	30.0 ± 28.2	65.6 ± 29.7	66.7 ± 30.3	1.1e-05	0.99998	0.204	(L)	0.99998	0.2	(L)	0.5716	0.488	(N)
3	Z	Gs	6	8	0.0 ± 0.0	38.9 ± 30.4	28.9 ± 28.7	8.3e-09	1.0	0.117	(L)	1.0	0.183	(L)	0.08613	0.596	(S)
3	R_y	Gs	6	8	61.9 ± 10.4	91.5 ± 9.1	90.7 ± 9.3	7.5e-13	1.0	0.027	(L)	1.0	0.029	(L)	0.37495	0.523	(N)
4	all	Gs	7	9	50.0 ± 6.5	75.3 ± 9.1	77.8 ± 9.8	1.4e-13	1.0	0.007	(L)	1.0	0.01	(L)	0.85839	0.422	(S)
4	X	Gs	7	9	30.0 ± 26.8	70.0 ± 25.3	77.8 ± 26.7	3.3e-08	1.0	0.157	(L)	1.0	0.122	(L)	0.91112	0.407	(S)
4	Z	Gs	7	9	2.2 ± 8.5	26.7 ± 30.8	33.3 ± 24.8	6.7e-07	0.99996	0.26	(L)	1.0	0.143	(L)	0.90273	0.41	(S)
4	R_y	Gs	7	9	72.6 ± 8.6	93.3 ± 8.0	92.6 ± 7.9	2.1e-11	1.0	0.06	(L)	1.0	0.064	(L)	0.33891	0.529	(N)
5	all	Gs	8	10	55.1 ± 6.3	78.2 ± 6.5	77.1 ± 7.4	8.3e-14	1.0	0.002	(L)	1.0	0.007	(L)	0.2889	0.541	(N)
5	X	Gs	8	10	37.8 ± 22.7	70.0 ± 22.1	74.4 ± 22.6	2.0e-07	1.0	0.179	(L)	1.0	0.151	(L)	0.78908	0.446	(N)
5	Z	Gs	8	10	0.0 ± 0.0	33.3 ± 26.3	20.0 ± 22.5	5.5e-08	1.0	0.133	(L)	0.99999	0.25	(L)	0.02205	0.64	(S)
5	R_y	Gs	8	10	79.3 ± 8.1	95.9 ± 5.4	97.0 ± 5.0	2.4e-12	1.0	0.066	(L)	1.0	0.052	(L)	0.79808	0.45	(N)
6	all	Gs	9	11	60.2 ± 8.1	76.9 ± 8.9	73.3 ± 9.9	1.6e-08	1.0	0.088	(L)	1.0	0.159	(L)	0.10905	0.591	(S)
6	X	Gs	9	11	33.3 ± 27.7	62.2 ± 30.0	58.9 ± 25.8	2.2e-04	0.99983	0.244	(L)	0.99977	0.252	(L)	0.29348	0.539	(N)
6	Z	Gs	9	11	1.1 ± 6.1	34.4 ± 27.0	34.4 ± 27.0	1.9e-08	1.0	0.146	(L)	1.0	0.146	(L)	0.50317	0.5	(N)
6	R_y	Gs	9	11	88.9 ± 9.2	95.9 ± 6.8	91.1 ± 9.9	0.00567	0.99926	0.282	(M)	0.86757	0.422	(S)	0.01709	0.642	(S)
7	all	Gs	10	12	64.0 ± 6.5	79.8 ± 7.9	76.2 ± 10.5	9.7e-09	1.0	0.066	(L)	0.99999	0.178	(L)	0.10466	0.593	(S)
7	X	Gs	10	12	26.7 ± 25.4	67.8 ± 27.0	64.4 ± 33.8	1.4e-06	1.0	0.153	(L)	0.99998	0.2	(L)	0.44677	0.51	(N)
7	Z	Gs	10	12	2.2 ± 8.5	43.3 ± 25.0	33.3 ± 29.0	5.1e-09	1.0	0.087	(L)	1.0	0.19	(L)	0.07616	0.602	(S)
7	R_y	Gs	10	12	97.0 ± 5.0	95.9 ± 5.4	94.4 ± 7.6	0.41799	0.20712	0.55	(N)	0.10011	0.58	(S)	0.29565	0.535	(N)
8	all	Gs	11	13	64.0 ± 4.5	80.2 ± 8.7	74.7 ± 9.5	9.3e-10	1.0	0.052	(L)	1.0	0.162	(L)	0.01844	0.653	(S)
8	X	Gs	11	13	18.9 ± 22.6	67.8 ± 23.9	54.4 ± 30.9	1.9e-08	1.0	0.092	(L)	0.99999	0.195	(L)	0.03986	0.622	(S)
8	Z	Gs	11	13	1.1 ± 6.1	40.0 ± 26.8	27.8 ± 23.3	5.5e-09	1.0	0.111	(L)	1.0	0.181	(L)	0.03742	0.625	(S)
8	R_y	Gs	11	13	100.0 ± 0.0	97.8 ± 4.5	97.0 ± 5.8	0.02159	0.00545	0.6	(S)	0.00276	0.617	(S)	0.35876	0.52	(N)
9	all	Gs	12	14	62.4 ± 3.7	78.9 ± 7.0	72.2 ± 7.2	1.6e-11	1.0	0.043	(L)	1.0	0.133	(L)	2.6e-04	0.753	(L)
9	X	Gs	12	14	12.2 ± 18.5	54.4 ± 27.0	46.7 ± 27.1	4.0e-08	1.0	0.119	(L)	1.0	0.169	(L)	0.14953	0.573	(N)
9	Z	Gs	12	14	0.0 ± 0.0	48.9 ± 25.9	21.1 ± 20.5	3.2e-12	1.0	0.033	(L)	1.0	0.217	(L)	3.1e-05	0.778	(L)
9	R_y	Gs	12	14	100.0 ± 0.0	97.0 ± 5.8	97.8 ± 4.5	0.02159	0.00276	0.617	(S)	0.00545	0.6	(S)	0.64893	0.48	(N)
10	all	Gs	13	15	63.8 ± 5.4	78.2 ± 9.3	75.3 ± 9.3	7.6e-09	1.0	0.098	(L)	1.0	0.139	(L)	0.07529	0.606	(S)
10	X	Gs	13	15	18.9 ± 27.2	55.6 ± 25.3	54.4 ± 30.9	5.4e-06	1.0	0.184	(L)	0.99998	0.206	(L)	0.41258	0.516	(N)
10	Z	Gs	13	15	0.0 ± 0.0	40.0 ± 32.0	26.7 ± 32.0	2.3e-07	1.0	0.15	(L)	0.99999	0.25	(L)	0.04676	0.62	(S)
10	R_y	Gs	13	15	100.0 ± 0.0	98.5 ± 3.8	98.5 ± 3.8	0.11409	0.02089	0.567	(N)	0.02089	0.567	(N)	0.50501	0.5	(N)
11	all	Gs	14	16	62.2 ± 4.4	78.9 ± 9.3	72.2 ± 7.0	2.3e-11	1.0	0.057	(L)	1.0	0.098	(L)	0.00198	0.711	(M)
11	X	Gs	14	16	11.1 ± 22.0	64.4 ± 27.6	40.0 ± 25.4	5.7e-10	1.0	0.08	(L)	1.0	0.182	(L)	4.1e-04	0.737	(M)
11	Z	Gs	14	16	0.0 ± 0.0	32.2 ± 25.5	30.0 ± 26.8	3.4e-08	1.0	0.15	(L)	1.0	0.167	(L)	0.3312	0.531	(N)
11	R_y	Gs	14	16	100.0 ± 0.0	99.3 ± 2.8	97.0 ± 5.0	0.00307	0.08037	0.533	(N)	0.00135	0.633	(S)	0.0202	0.6	(S)
12	all	Gs	15	17	63.3 ± 4.9	78.9 ± 9.1	69.1 ± 8.1	7.0e-09	1.0	0.084	(L)	0.999	0.279	(M)	4.6e-05	0.788	(L)
12	X	Gs	15	17	16.7 ± 24.4	61.1 ± 30.4	38.9 ± 26.4	5.0e-07	1.0	0.139	(L)	0.99963	0.264	(M)	0.00278	0.698	(M)
12	Z	Gs	15	17	0.0 ± 0.0	40.0 ± 28.2	20.0 ± 20.7	5.1e-09	1.0	0.117	(L)	1.0	0.233	(L)	0.00239	0.699	(M)
12	R_y	Gs	15	17	100.0 ± 0.0	97.8 ± 4.5	95.6 ± 7.5	0.00604	0.00545	0.6	(S)	6.7e-04	0.65	(S)	0.14743	0.56	(N)
13	all	Gs	16	18	64.7 ± 4.7	82.9 ± 9.7	72.7 ± 9.8	5.2e-10	1.0	0.051	(L)	0.99994	0.223	(L)	1.4e-04	0.769	(L)
13	X	Gs	16	18	23.3 ± 23.4	68.9 ± 30.2	45.6 ± 29.7	1.1e-06	1.0	0.139	(L)	0.99833	0.293	(M)	0.0027	0.701	(M)
13	Z	Gs	16	18	0.0 ± 0.0	48.9 ± 31.2	21.1 ± 25.5	1.5e-10	1.0	0.067	(L)	0.99999	0.25	(L)	2.2e-04	0.749	(L)
13	R_y	Gs	16	18	100.0 ± 0.0	98.9 ± 3.4	98.9 ± 4.5	0.23577	0.0407	0.55	(N)	0.0804	0.533	(N)	0.66715	0.485	(N)

References

[1] Simon Anders and Hans J. Briegel. 2006. Fast simulation of stabilizer circuits using a graph-state representation. *Phys. Rev. A* 73 (Feb 2006), 022334. Issue 2. https://doi.org/10.1103/PhysRevA.73.022334

[2] Lov K. Grover. 1996. A Fast Quantum Mechanical Algorithm for Database Search. In *Proceedings of the Twenty-Eighth Annual ACM Symposium on Theory of Computing* (Philadelphia, Pennsylvania, USA) *(STOC '96)*. Association for Computing Machinery, New York, NY, USA, 212–219. https://doi.org/10.1145/237814.237866

[3] M. Hein, J. Eisert, and H. J. Briegel. 2004. Multiparty entanglement in graph states. *Physical Review A* 69, 6 (jun 2004). https://doi.org/10.1103/physreva.69.062311

[4] Shahin Honarvar, Mohammad Reza Mousavi, and Rajagopal Nagarajan. 2020. Property-Based Testing of Quantum Programs in Q#. In *Proceedings of the IEEE/ACM 42nd International Conference on Software Engineering Workshops* (Seoul, Republic of Korea) *(ICSEW'20)*. Association for Computing Machinery, New York, NY, USA, 430–435. https://doi.org/10.1145/3387940.3391459

[5] E.R. Johnston, N. Harrigan, and M. Gimeno-Segovia. 2019. *Programming Quantum Computers: Essential Algorithms and Code Samples*. O'Reilly Media, Incorporated.

[6] Salvador Elías Venegas-Andraca. 2012. Quantum walks: a comprehensive review. *Quantum Information Processing* 11, 5 (July 2012), 1015–1106. https://doi.org/10.1007/s11128-012-0432-5