Simulating Single Qubit Random

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Introduction & Motivation

- Gate fidelity is measured with various methods (XEB, QPT, RB).
- RB looks solely at gate error, not state initialization nor read out error (ignores SPAM errors).
- SQMS data produces odd results that do not look like industry-standard RB.
- Motivation of project is to gain insight on programming v.s hardware issues by creating a simulation.

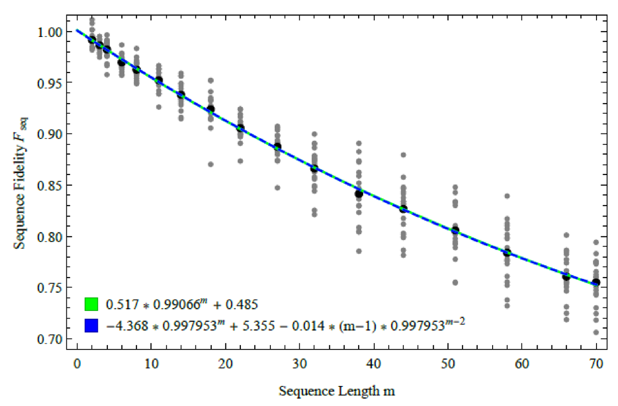

Figure 1: Experimental data from single qubit RB [1].

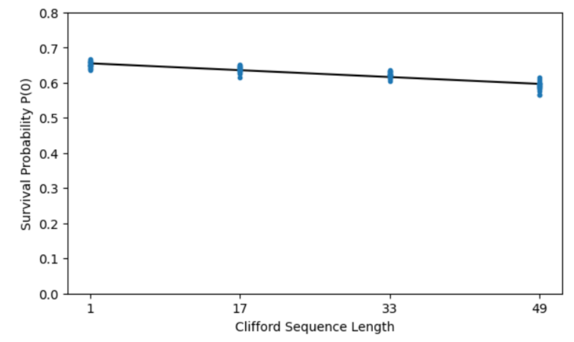

Figure 2: Experimental data from SQMS single qubit RB.

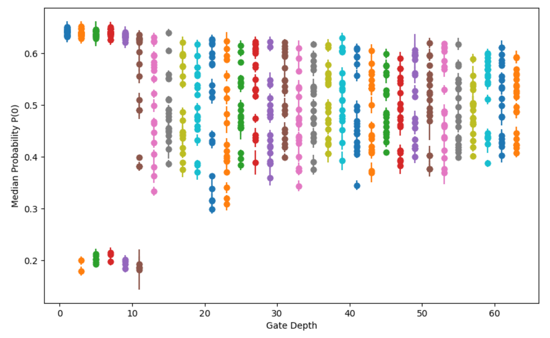

Figure 3: Experimental data from SQMS single qubit RB

Approach

- Clifford gates written in a dictionary.
- Number of randomized sequences produced per gate depth.
- Used Cayley table to navigate between gates.
- Utilize Bloch sphere to visualize gate rotations.
- Probability of ground state calculated as modulo squared of state's matrix.

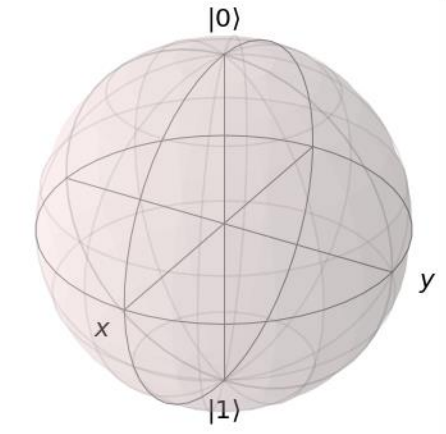

Figure 4: Two-level Bloch sphere.

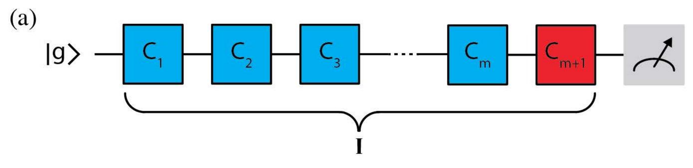

Figure 4: Randomized sequence of Clifford gates.

Fit Used & Fidelity Calculation

- Fidelity calculation and fit:

$$r = 1 - p - \frac{1-p}{2}$$

Implementing Coherent Noise

- Defined rotation gates for X and Y.

$$R_x(\theta) = \begin{pmatrix} \cos\left(\frac{\theta}{2}\right) & -i\sin\left(\frac{\theta}{2}\right) \\ -i\sin\left(\frac{\theta}{2}\right) & \cos\left(\frac{\theta}{2}\right) \end{pmatrix} \qquad R_y(\theta) = \begin{pmatrix} \cos\left(\frac{\theta}{2}\right) & -\sin\left(\frac{\theta}{2}\right) \\ \sin\left(\frac{\theta}{2}\right) & \cos\left(\frac{\theta}{2}\right) \end{pmatrix}$$

- Scaled the theta value for these gates by decimal values.

Simulation Results

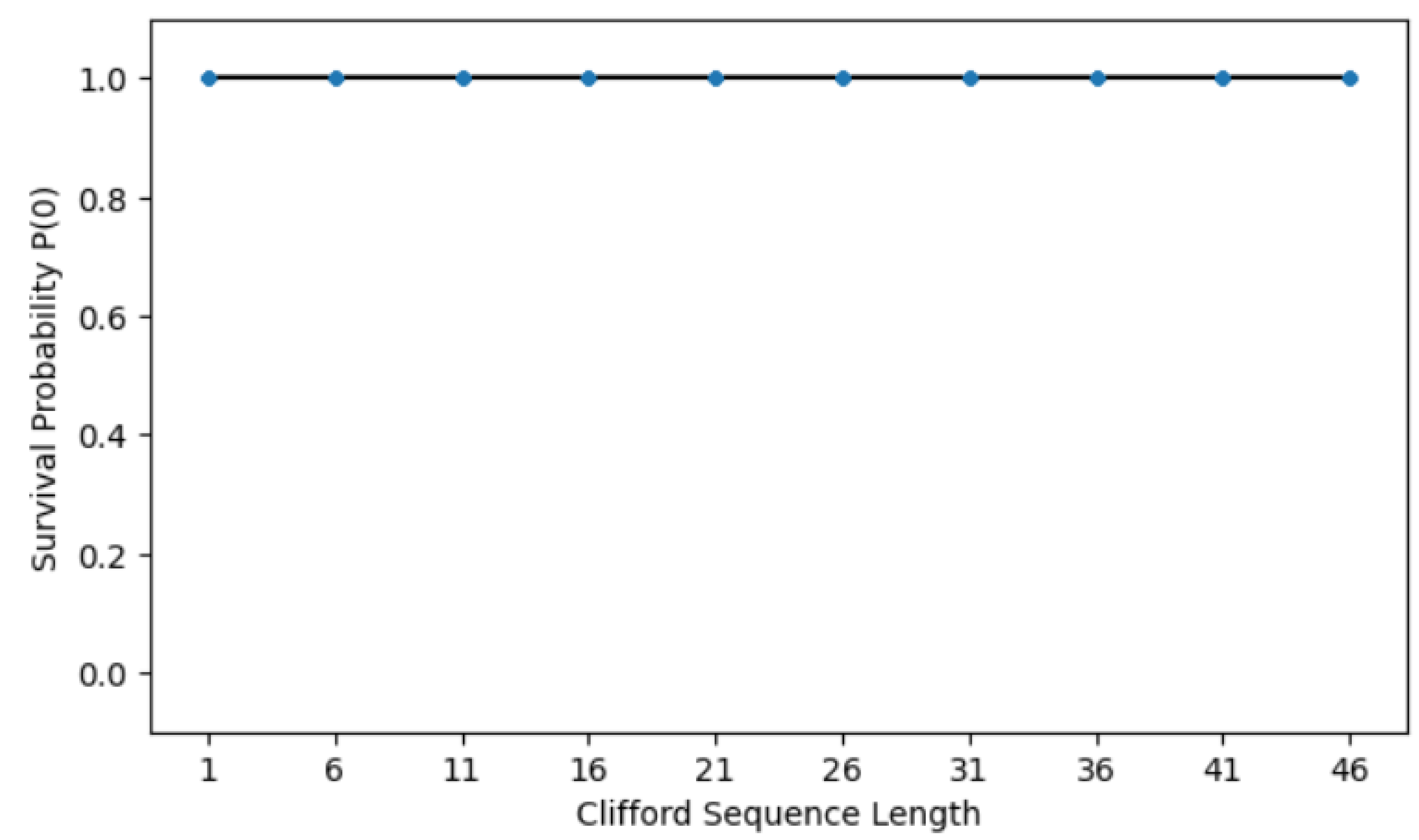

Figure 5: Probability of ground state as a function of gate depth. Plotted points are one sequence. Graph incorporates ideal gates.

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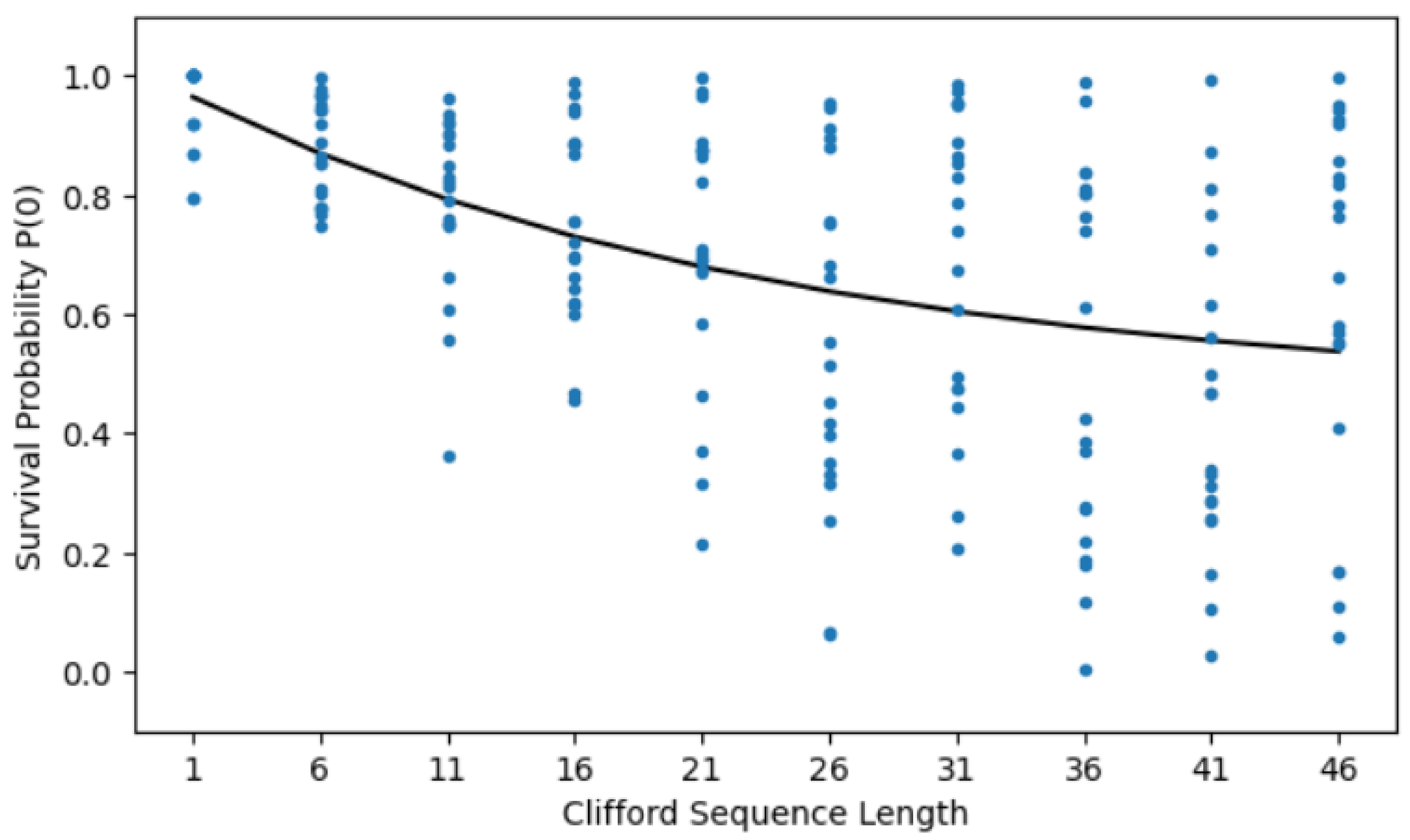

Figure 6: Probability of ground state as a function of gate depth. Plotted points are one sequence. Graph incorporates noisy gates.

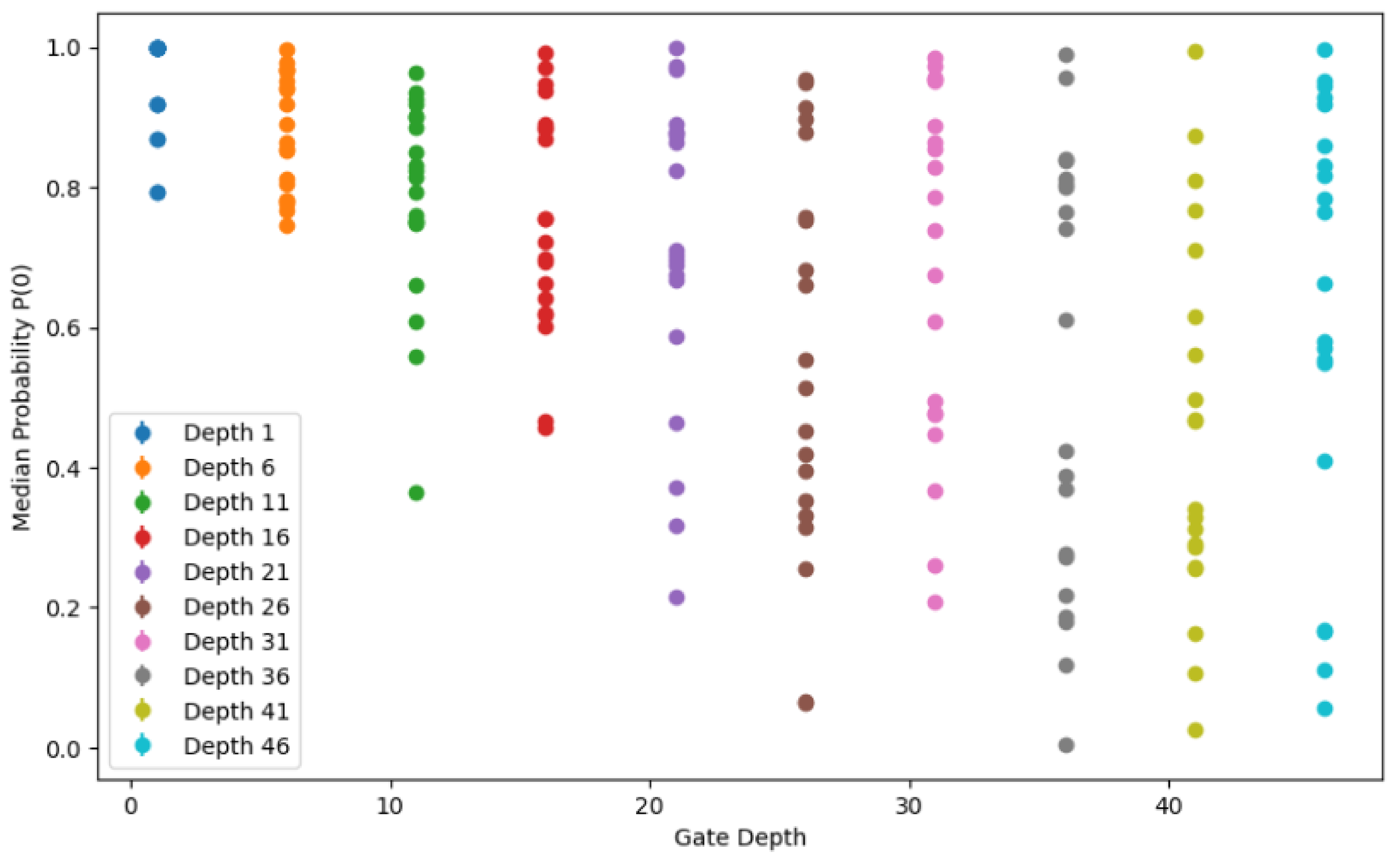

Figure 7: Median probability of ground state for each sequence. Graph incorporates noisy gates and has repetitions per sequence.

Conclusion & Next Steps

- Simulation produced expected results from noise-less simulation. Noisy simulation data had an odd spread.
- Explore potential issues with virtual Z-gates causing noise.
- Work on two qubit simulation.

References

- [1] Samuel Haberthur, Haberthur, **Randomized Benchmarking of Two-Qubit Gates**, Master's Thesis, Dept. of Phys., Swiss Federal Institute of Technology Zurich, Zurich, 2015.