The battle of clean and dirty qubits in the era of partial error correction

Daniel Bultrini
Samson Wang, Piotr Czarnik, M.H. Gordon, M. Cerezo, Patrick J. Coles, Lukasz Cincio

Universität Heidelberg, INF 229, Heidelberg, Germany & *Theoretical Division, Los Alamos National Laboratory, Los Alamos, USA*

daniel.bultrini@pci.uni-heidelberg.de

Error correction is becoming an experimental reality [1], but it comes at the cost of dedicating many physical qubits to generate one 'logical' qubit. So what happens if you decide to create a machine with both error-corrected and physical qubits to be used together? This work [1] begins to answer this question by considering the capabilities of a simplified model of noisy and noiseless qubits, which is further developed to include realistic error correction. We find that we do indeed get an exponential suppression of errors by mixing the two types of qubits, as well as the exponential increase in computational space given by the additional qubits. This could extend the computational reach of smaller fault-tolerant machines.

References

[1] Egan, Laird, et al., Nature 598 (2021), 281-286

[2] Bultrini, Daniel, et al., *arXiv preprint arXiv:2205.13454* (2022).

Figures

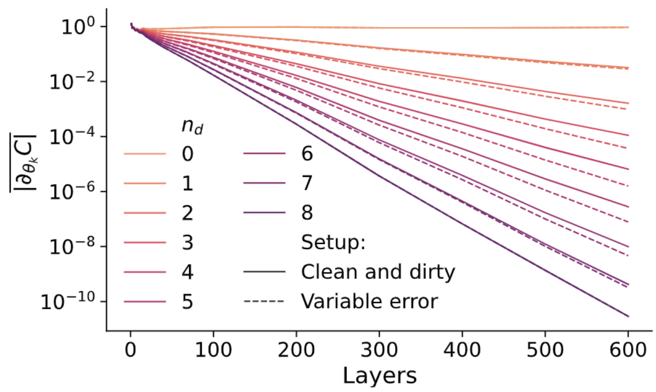

Figure 1: Plot showing the decay of the mean magnitude of gradients over the depth of the circuit (layers) as you increase the number of 'dirty' or physical qubits n_d. This is compared to lowering the overall error rate of the machine.

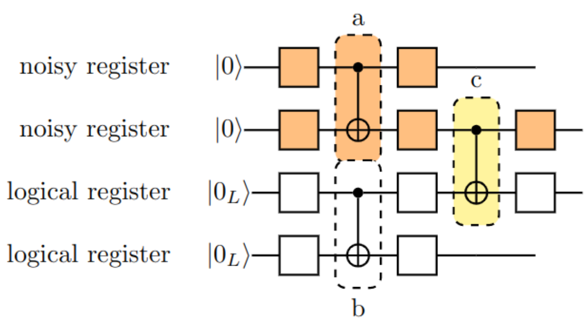

Figure 2: Circuit diagram showing the clean and dirty setup with gate types "a" (orange) which are standard noisy gates on our 'dirty' qubits, gate types "b" (white) which are encoded logical gates acting on the 'clean' qubits, and gate types "c" (yellow) which couple the clean and dirty qubits.