ASPLOS: Quantum Applications

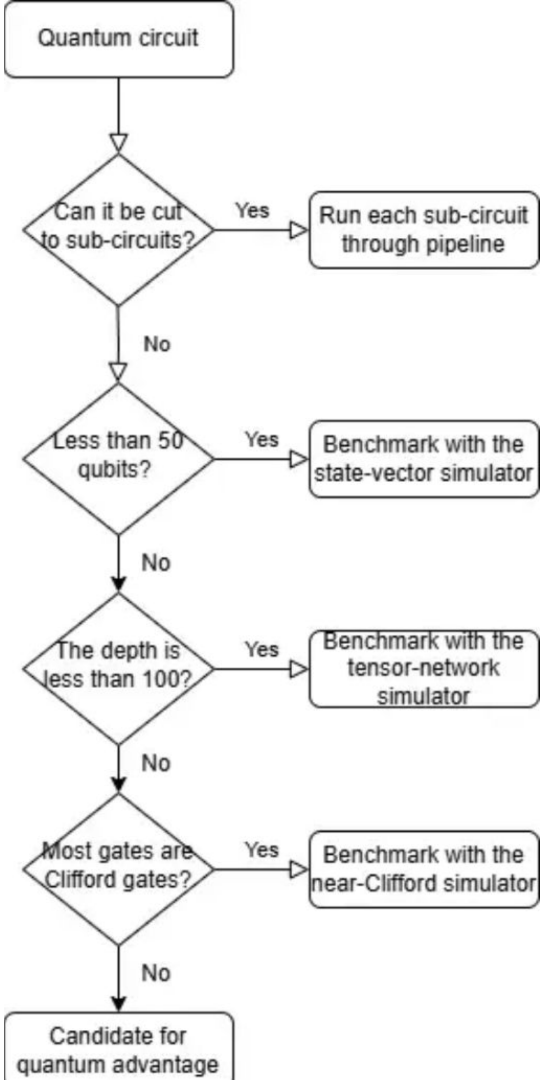
Yuri Alexeev
Argonne National Laboratory

April 28, 2024

Quantum Applications Topics

- demonstration of quantum advantage/utility
- transition of quantum algorithms from NISQ to partially fault-tolerant quantum devices
- distributed quantum algorithms
- high-impact quantum applications
- quantum resource estimation

Quantum benchmarks:



QML Results

Theorem 1 (Informal). *For a sparse machine learning model with model size n, running T iterations, with the algorithm being fully dissipative (whose formal definition is given in the Appendix), there is a quantum algorithm that runs in*

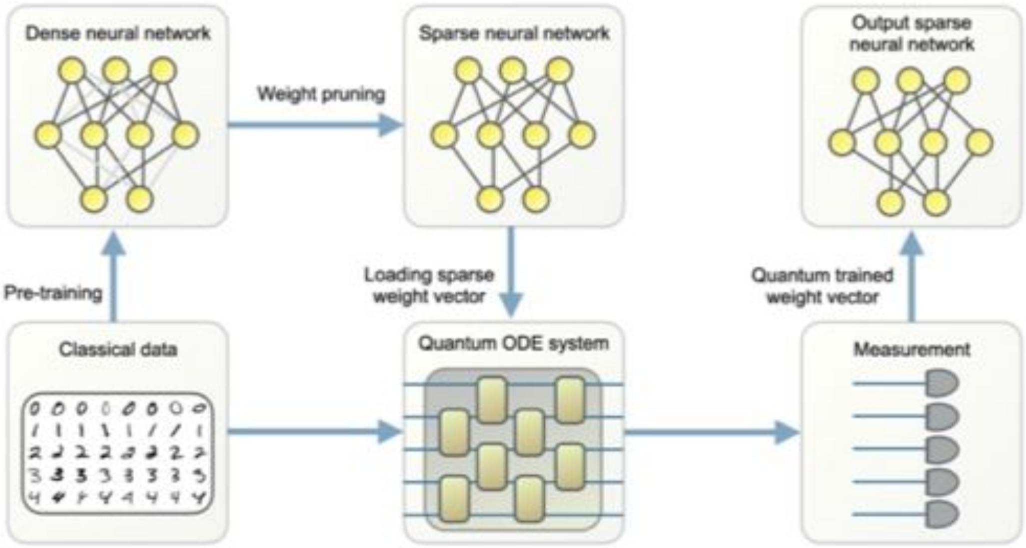
$$\mathcal{O}\left(T \times \text{poly}\left(\log n, \frac{1}{\epsilon}\right)\right) \quad (1)$$

time with precision $\epsilon > 0$. The sparsity condition also ensures the efficiency of uploading and downloading quantum states towards classical processors.

Theorem 2 (Informal). *For a machine learning model with model size n, running in T iterations, and the algorithm is almost dissipative (whose formal definition is given in the Appendix), then there is a quantum algorithm runs in*

$$\mathcal{O}\left(T^2 \times \text{poly}\left(\log n, \frac{1}{\epsilon}\right)\right) \quad (2)$$

time with precision $\epsilon > 0$. The sparsity condition also ensures the efficiency of uploading and downloading quantum states towards classical processors.

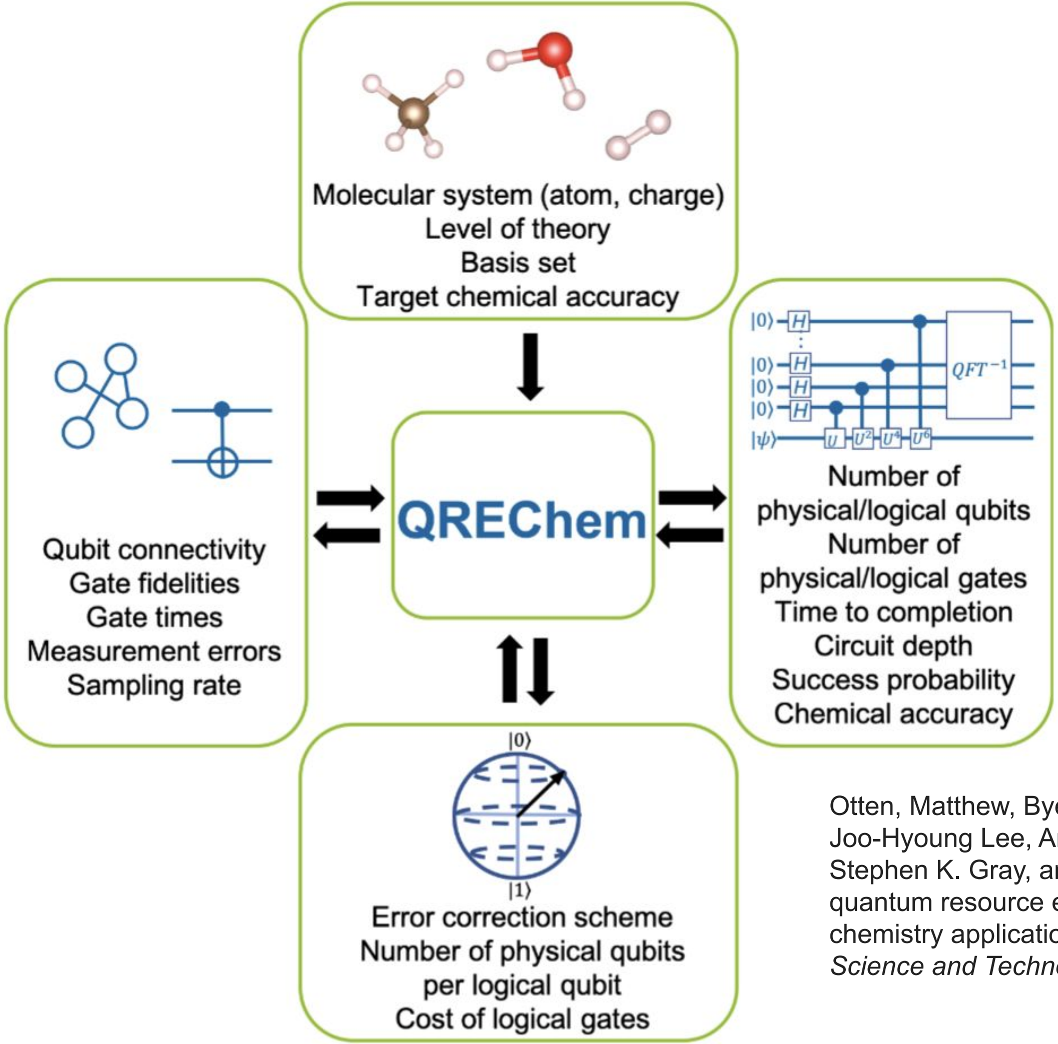


O(100) billion trainable parameters, highly overparametrized

If designing quantum algorithms linear or event constant in T, polylog in number of parameters N.

N=10^11, log N = 36.5. Quantum: 1s, Classical: 87 years.
Quantum 0.01s, Classical: 1 year.

Liu, Junyu, Minzhao Liu, Jin-Peng Liu, Ziyu Ye, Yunfei Wang, Yuri Alexeev, Jens Eisert, and Liang Jiang. "Towards provably efficient quantum algorithms for large-scale machine-learning models." *Nature Communications* 15, no. 1 (2024): 434.



Otten, Matthew, Byeol Kang, Dmitry Fedorov, Joo-Hyoung Lee, Anouar Benali, Salman Habib, Stephen K. Gray, and Yuri Alexeev. "QREChem: quantum resource estimation software for chemistry applications." *Frontiers in Quantum Science and Technology* 2 (2023): 1232624.