SRC @ ICCAD

ML for Quantum and Quantum for ML: Towards Robust Quantum Computing on NISQ Devices

Hanrui Wang, Song Han (MIT)

torchquantum.org

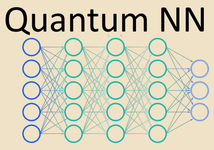
qmlsys.mit.edu

Why Quantum + ML and the challenges

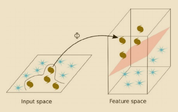
Quantum Computing promises computational advantages over conventional methods for many important applications including ML. Proved advantage on QNN for quantum data has been achieved.

- Challenge: How to make the QML **more robust** on current machines?
- Challenge: How to make the QML algorithm **design process more efficient**?

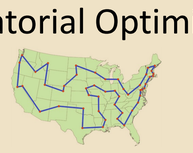
Quantum NN



Quantum SVM



Combinatorial Optimization



Number Factorization

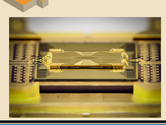
Quantum machines with 100+ qubits are available now! But they contain significant **error/noises**, data-driven ML can **help estimate and mitigate noise**

- Challenge: How to design **scalable** estimation / mitigation ML models?
- Challenge: How to make the classical ML processing **fast and efficient** enough?

IBM

Google

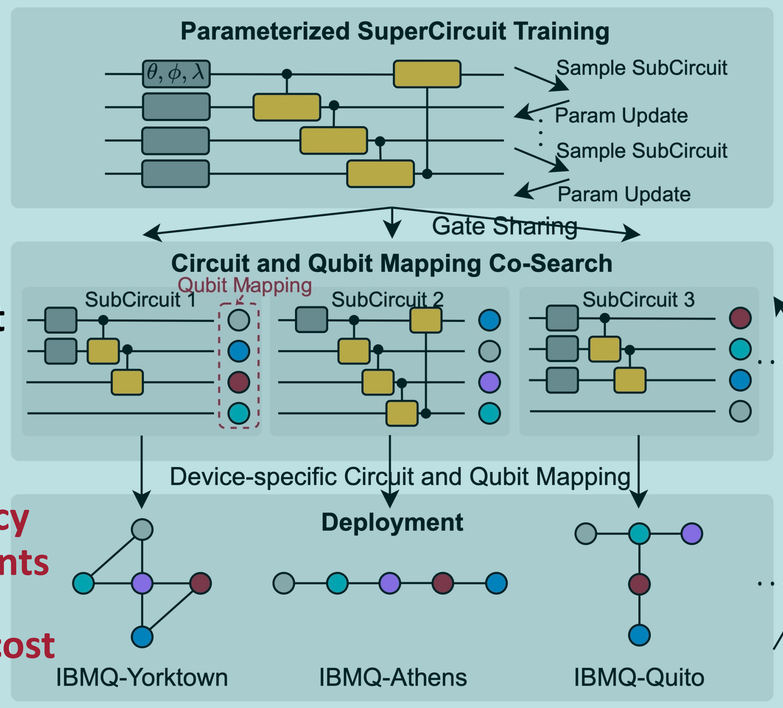
IONQ



atom computing

Quantum for Machine Learning

Quantum Circuit Architecture Design

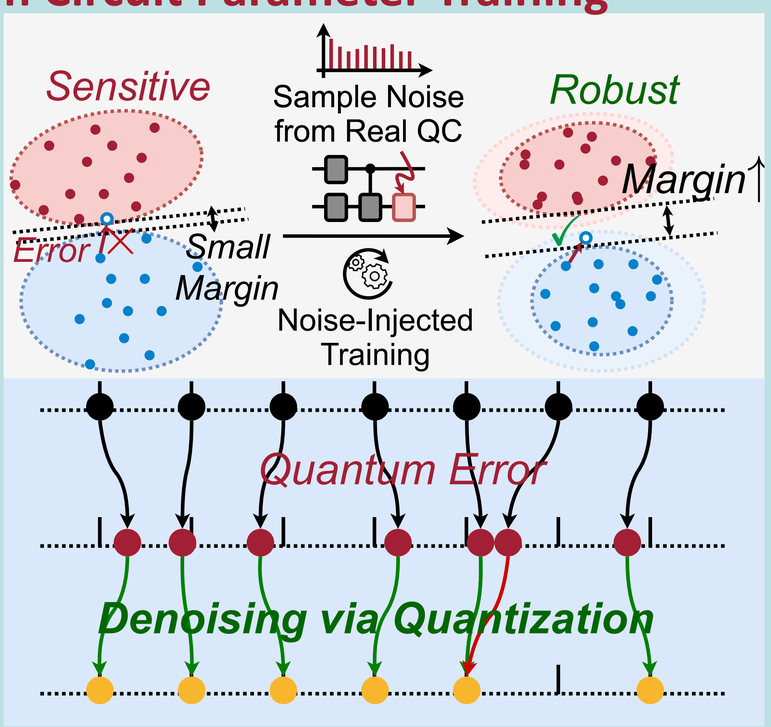


SuperCircuit -SubCircuit Framework

33% accuracy improvements

1000x less cost

Quantum Circuit Parameter Training

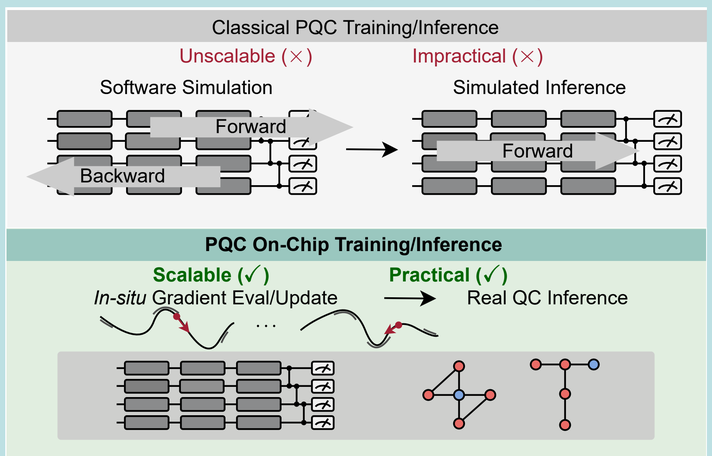


Noise Gate injection

Quantization of measurement outcomes

43% accuracy improvements

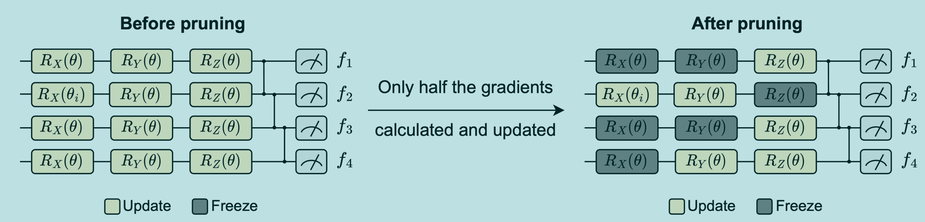
Quantum Circuit On-Chip Tuning



Parameter-Shift rule to obtain on-chip gradients

90% 2-class accuracy trained on quantum

Gradient pruning stabilizes training



QOC: On-Chip Training with Gradient Pruning [DAC'22]

Challenge

Search Efficiency ↑

Estimation Scalability ↑

Training Scalability ↑

Energy Efficiency ↑

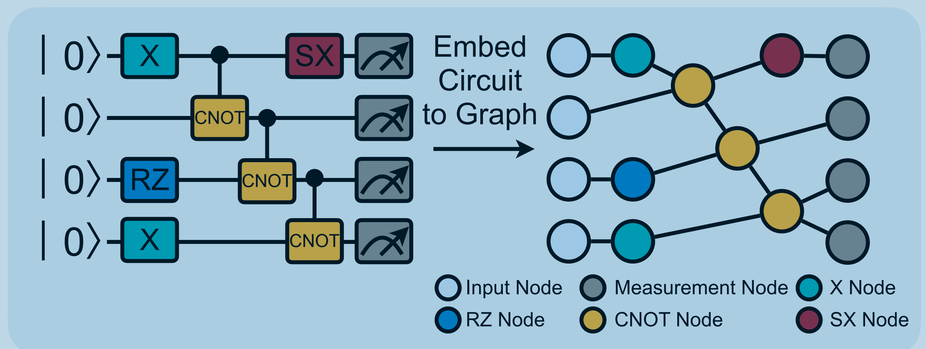
Circuit Robustness ↑

Inference Speed ↑

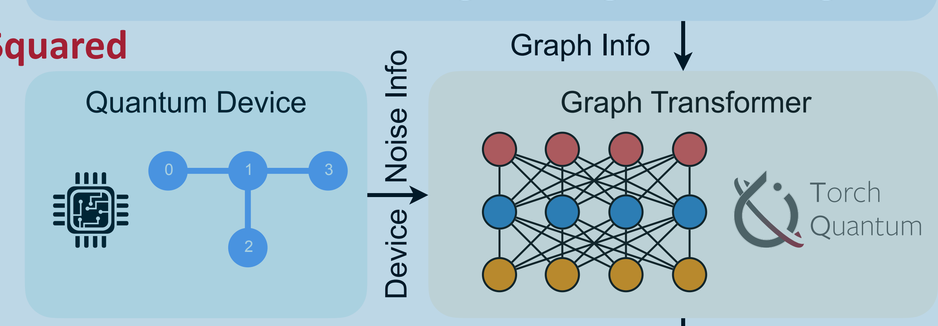
Machine Learning for Quantum

Learning Quantum Noise with NN

Embed quantum circuit to graph



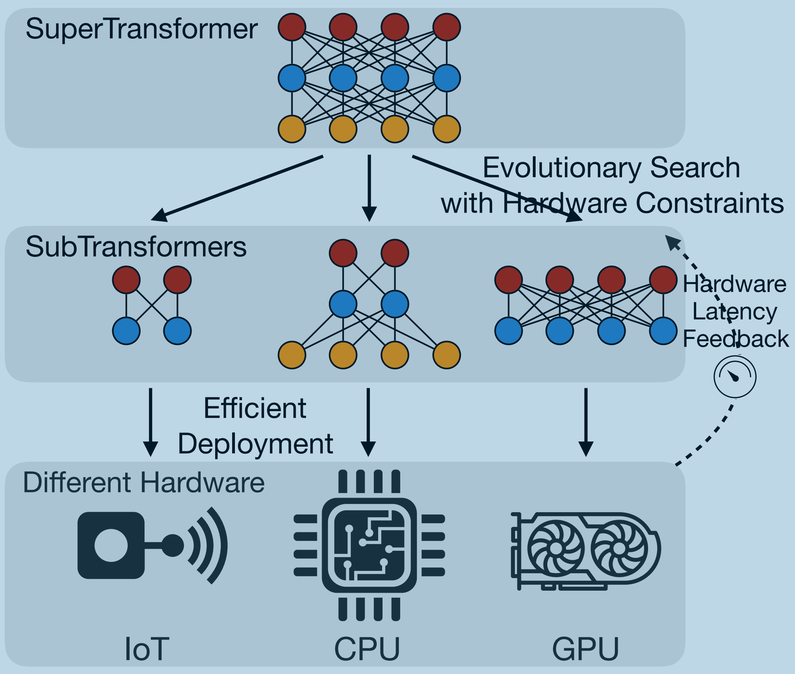
>0.95 R-Squared



QuantumNAS: Noise-Aware Arch Search [HPCA'22]

QuEst: Transformer for Quantum Reliability Estimation [ICCAD'22]

Classical NN Model Architecture Design



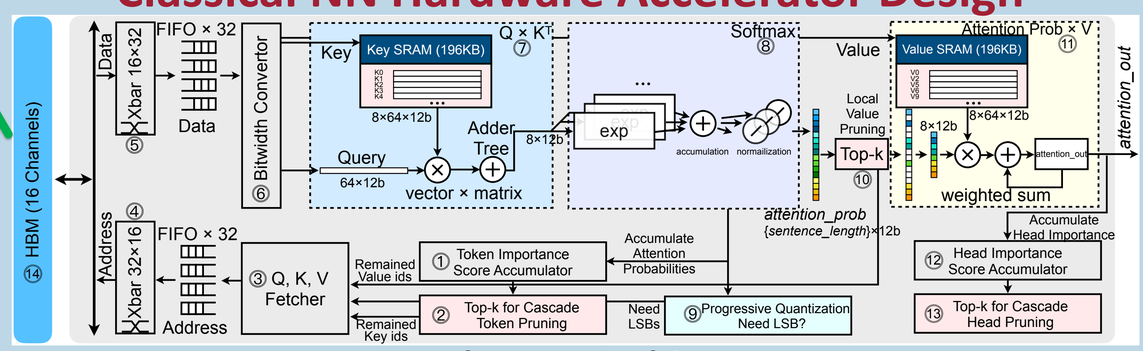
Search for the most efficient and fast transformer model

2.7x speedup
3.6x smaller size
10000x less cost

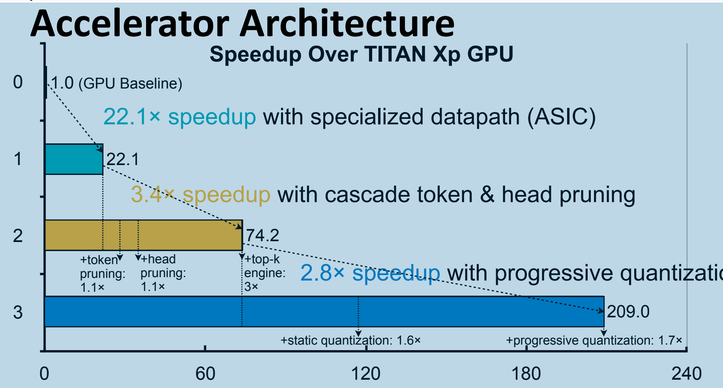
QuantumNAT: Noise-Aware Param Training [DAC'22]

HAT: Hardware-Aware Transformer NAS [ACL'20]

Classical NN Hardware Accelerator Design



209x speedup
1100x energy saving over GPU



SpAtten: Sparse Transformer Accelerator [HPCA'21]

Wang, H., Ding, Y., Gu, J., Lin, Y., Pan, D. Z., Chong, F. T., & Han, S. QuantumNAS: Noise-adaptive search for robust quantum circuits. ***HPCA 2022***

Wang, H., Gu, J., Ding, Y., Li, Z., Chong, F. T., Pan, D. Z., & Han, S. QuantumNAT: Quantum Noise-Aware Training with Noise Injection, Quantization and Normalization. ***DAC 2022***

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References

Wang, H., Liu, P., Cheng, *et al* QuEst: Graph Transformer for Quantum Circuit Reliability Estimation. ***ICCAD 2022***

Wang, H., Wu, Z., Liu, Z., Cai, H., Zhu, L., Gan, C., & Han, S. Hat: Hardware-aware transformers for efficient natural language processing. ***ACL 2022***

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