Quantum Machine Learning with SQUID

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Machine Learning and Quantum Computing

- Machine Learning learns patterns from many, many examples.
- Quantum Computing allows parallelization among many qubits, and can provide significant speed-ups.
- It also *might* be better at representing and learning complex patterns.
- Why not both?

Near-Term Quantum Computing

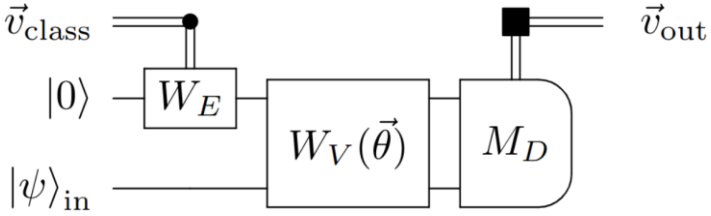
- Quantum computers are small! (Biggest are ~100 qubits).
- They are also very noisy, not allowing to run them for long.
- Quantum algorithms are still incredibly powerful and can be trained on small datasets.
- What about datasets that are larger than modern quantum computers?

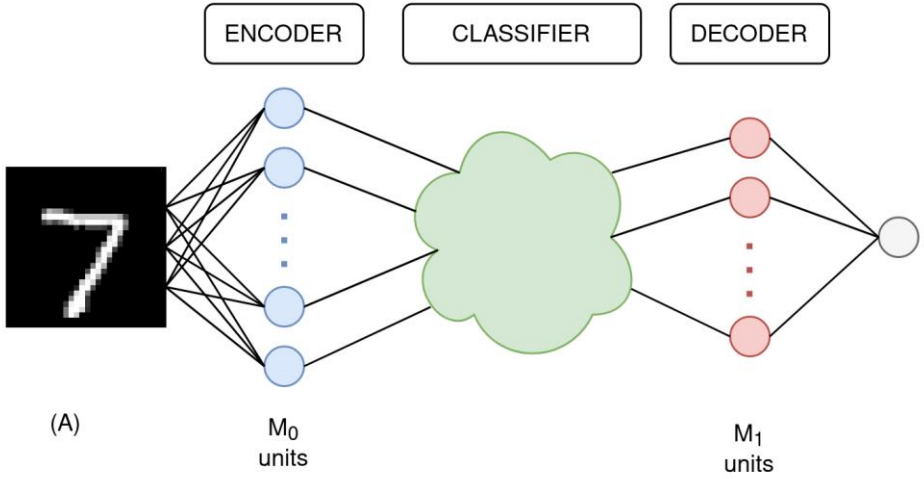
SQUID (Scalable QUantum IDentifier)

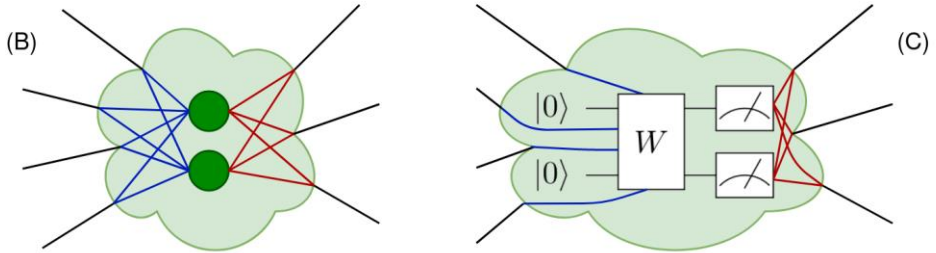
- Enables for scaling quantum algorithms to varied-sized datasets, through linking classical and quantum machine learning.
- Passes gradients under-the-hood removing overhead for the user.
- Allows for arbitrary, sub-differentiable quantum algorithms.

SQUID Architecture

- 3 sub-models:
  - Encoder and Decoder - classical
  - Classifier - classical OR quantum







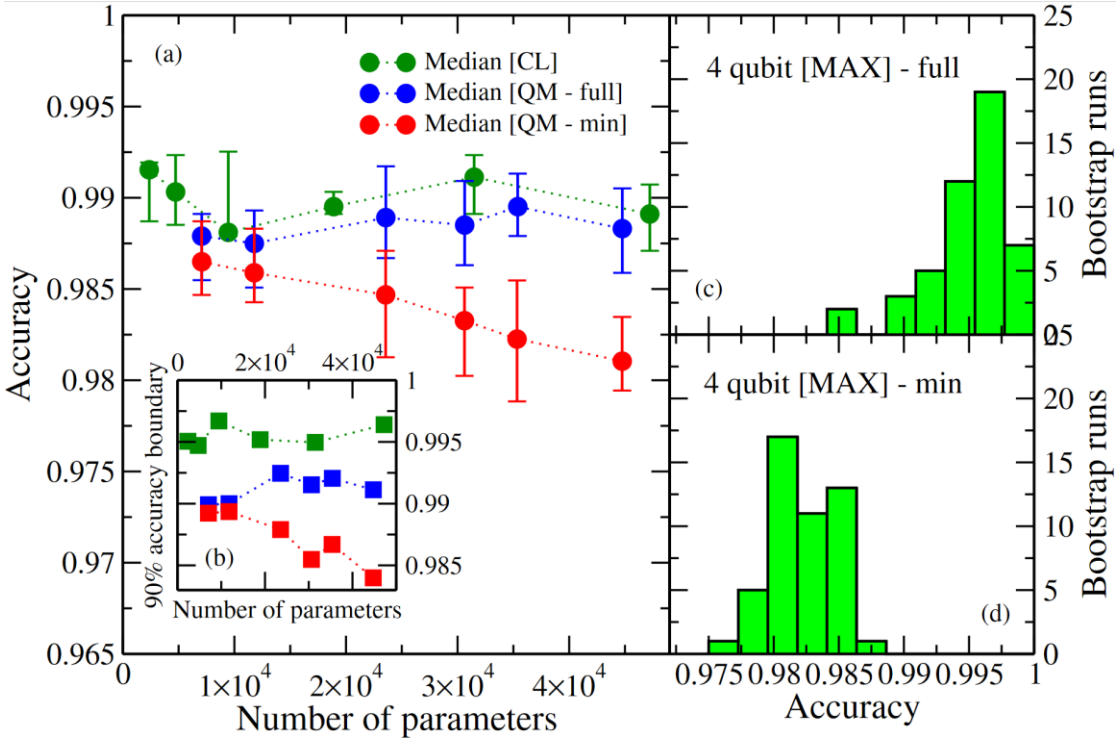
Experiment - Motivation

- Not a lot of qubits available, so we should not want to waste them
- A lot of binary classification problems (2 classes) will only use output of first qubit (*0* or *1*) to predict a class
- With decoder in SQUID architecture there is close to 0 overhead in using information from all qubits.

Experiment - Setup

- **MNIST dataset (784 pixels)**
  - **Digits 3 vs 8 is a *hard* problem**
  - **Digits 3 vs 7 is an *easy* problem**
- **Models used have 2, 4 or 6 qubits and various complexities of circuits**
- **We compare performance among using all qubits and only first one.**
- **And compare classical vs quantum models.**

One qubit vs. Using all qubits



- Full quantum model performs on-par with classical model.
- Model using single qubit underperforms
  - Especially when number of qubits is higher.

Takeaways & Links

- **Try SQUID if you want to try training a quantum algorithm on large dataset.**
- **Do not use output of just single qubit in your model.**

- **Paper is out on arXiv (2105.00098)**
- **Check out SQUID with `pip install squid` or on BitBucket!**

Thank you!

Questions?