Improving the speed of variational quantum algorithms for quantum error correction

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Agenda

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SUMMARY OF PAPER

Error detection is important for **quantum computers** since they have **larger error** than **classical computers**

- Current Challenges
  - Phenomenon of **barren plateaus**
  - Difficulty determining encoding and correction unitary gates
  - Reliant on **type of noise**
- VQAs (Variational Quantum Algorithms) to optimize error correction parameters
  - Parameters: alpha and beta control vectors
  - **Bit-flip** and **phase-flip** noise simulation
  - Parameters updated based on **gradients of cost function**

THEORY

Fidelity Distance

- Measures the closeness of two quantum states
  - Unitarily invariant
  - Susceptible to barren plateaus

Quantum Wasserstein Distance Order 1

- Measures number of differing qubits between two states
  - Not unitarily invariant
  - Results in a larger gradient when regions are far from local minima
  - Gradient of the cost function will not decay exponentially and the phenomenon of barren plateaus can be improved in certain cases

KEY RESULTS

Comparing performance of **Fidelity** and **Wasserstein** cost functions

- Fidelity cost function with bit-flip noise yields same average fidelity as **no error correction** (Fig. 1)
  - Very high number of iterations for convergence (~2000) (Fig. 2)
- Wasserstein cost function achieves **faster convergence** (Fig. 2)

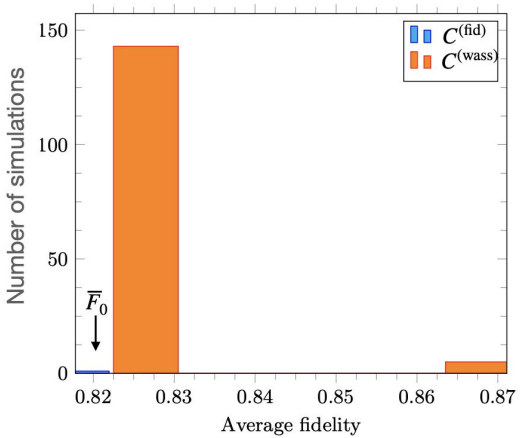

Figure 1

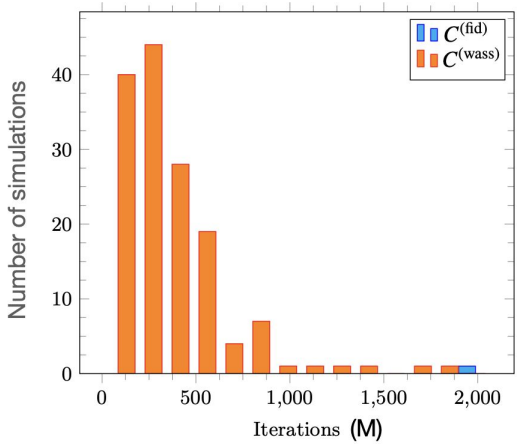

Figure 2

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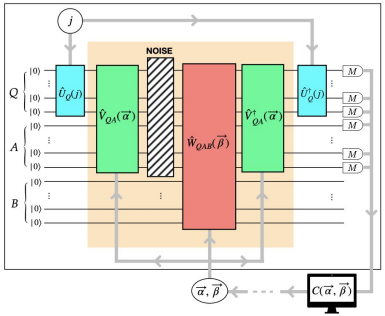
SOFTWARE DESIGN



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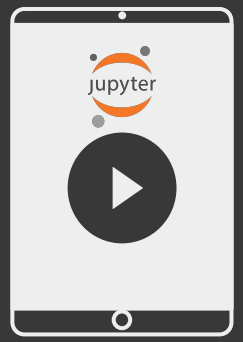
Project Demo



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Issues and Reproducibility

Issues

- Missing information:
  - Gradient Descent Momentum model and parameters
  - Initial values
  - Noise model
- Confusing equation definitions
- Misleading typos

Reproducibility

- Time constraints
- Machine limitations
- Supports findings
  - Wasserstein Cost
  - VQA for QEC

References

- https://arxiv.org/pdf/2301.05273v1.pdf
- https://pennylane.ai/qml/demos/tutorial_haar_measure.html
- https://pennylane.ai/qml/demos/tutorial_unitary_designs.html