Error Mitigation with Mitiq

Nate Stemen

Sep 18, 2023

Unitary Fund

TEAM Tough Errors Are No Match

Follow along!

`https://github.com/unitaryfund/mitiq-tutorial`

Experience

1. Who has written a quantum program before?

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2. Who has run a quantum program on hardware before?

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4. Who has used Mitiq?

Tutorial goals

1. Understand context, and general ideas of quantum error mitigation (QEM).
2. Understand main ideas of ZNE, PEC, and DDD along with pros and cons of each technique.
3. Ability to use Mitiq to apply these techniques in a quantum pipeline.

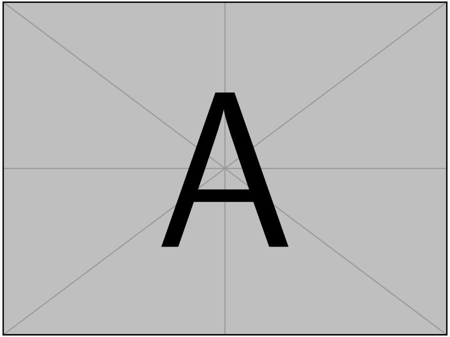
What is Quantum Error Mitigation?

Quantum Error Mitigation

The acceptance that available quantum devices are noisy. . . maybe very much so.

But we still want to use them!

- (In)coherent noise
- SPAM errors
- Crosstalk
- Calibration errors
- . . .

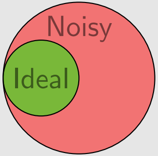


QEM Methods

Zero-Noise Extrapolation

$$\partial_t \rho = -i[H,\rho] + \lambda \mathcal{L}(\rho)$$

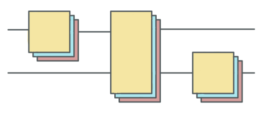
Symmetry-based techniques



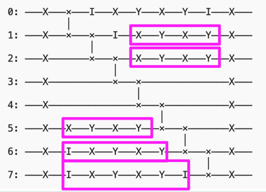
$$M\,|\psi\rangle = |\psi\rangle$$

$$\rho = \frac{M\rho M}{\mathrm{tr}(M\rho)}$$

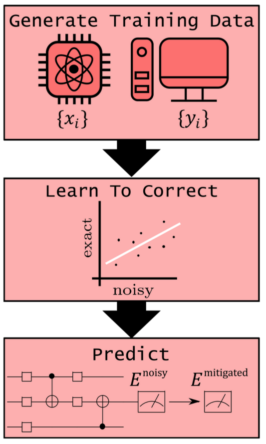
Probabilistic Error Cancellation



Dynamical Decoupling



Learning-based methods



What about error correction?

Scheme for reducing decoherence in quantum computer memory

Peter W. Shor*

AT&T Bell Laboratories, Room 2D-149, 600 Mountain Avenue, Murray Hill, New Jersey 07974

(Received 17 May 1995)

Recently, it was realized that use of the properties of quantum mechanics might speed up certain computations dramatically. Interest has since been growing in the area of quantum computation. One of the main difficulties of quantum computation is that decoherence destroys the information in a superposition of states contained in a quantum computer, thus making long computations impossible. It is shown how to reduce the effects of decoherence for information stored in quantum memory, assuming that the decoherence process acts independently on each of the bits stored in memory. This involves the use of a quantum analog of error-correcting codes.

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- Encode logical qubits into many physical qubits
- Intermediate measurements produce syndromes
- Use syndromes to correct errors

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- Collect results
- Infer ideal expectation values

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Unscalable*, but feasible

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Key Idea

Scale noise up, extrapolate back to zero-noise value.

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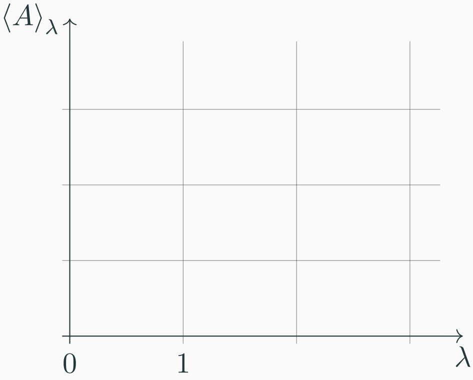

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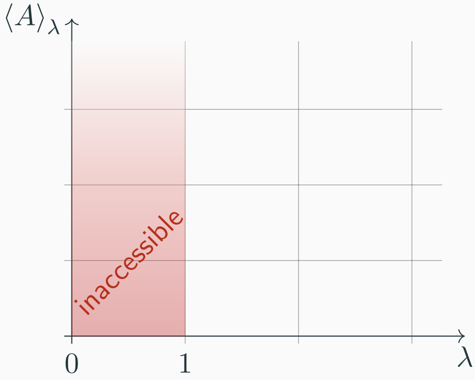

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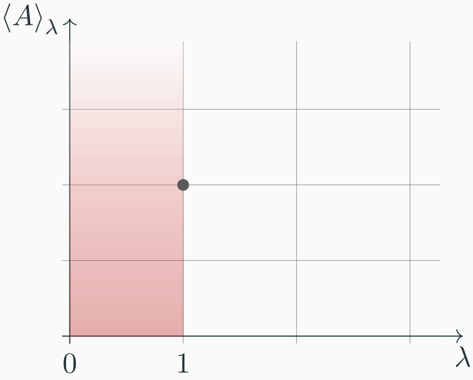

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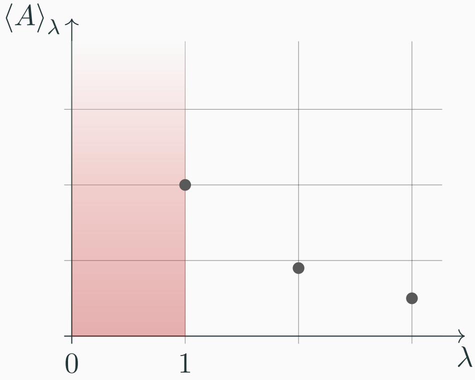

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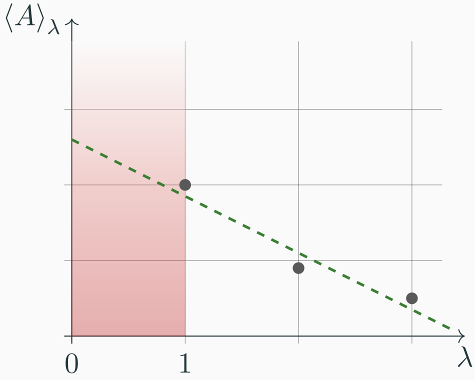

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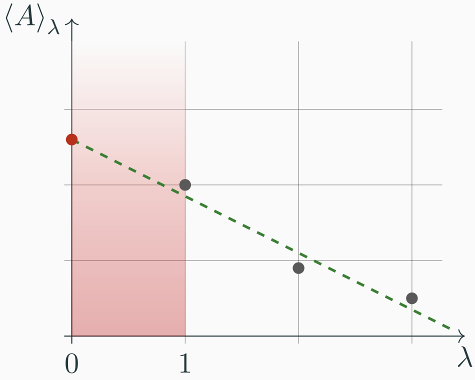

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How do we scale the noise **up**?

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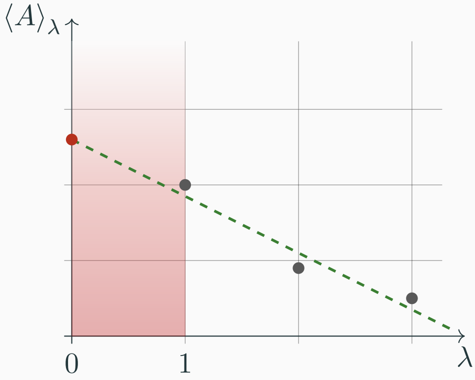

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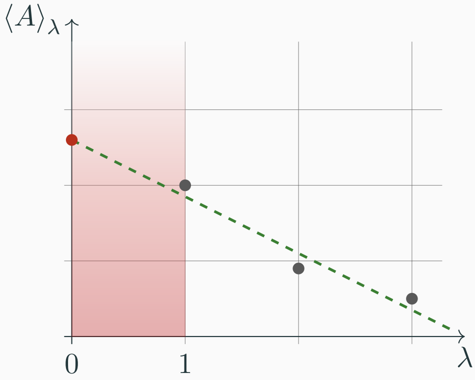

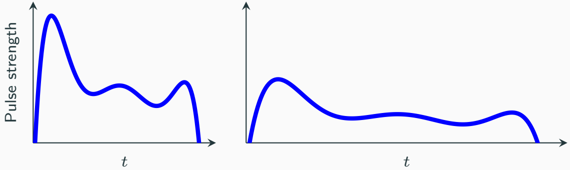

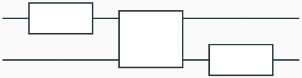

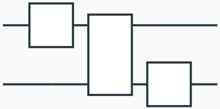

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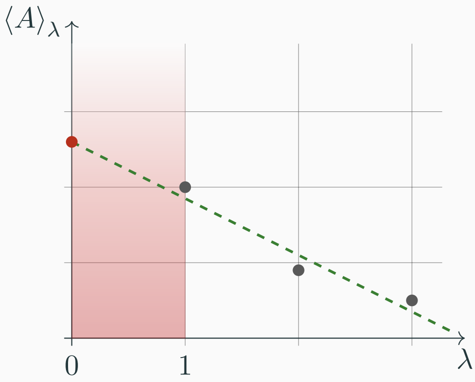

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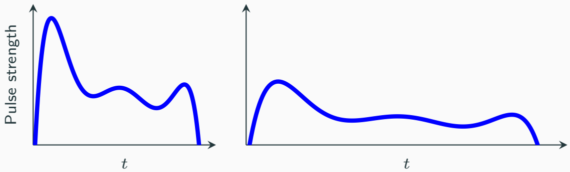
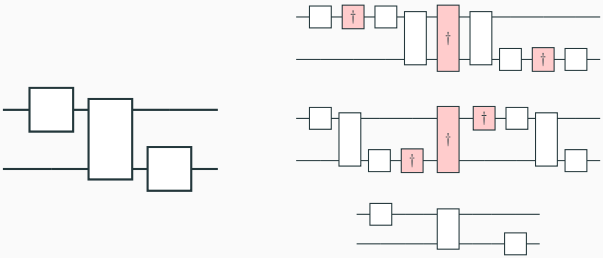
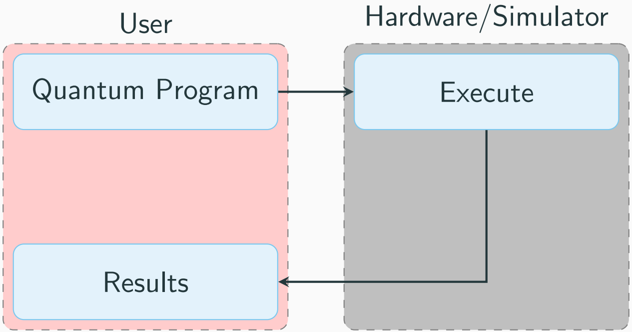
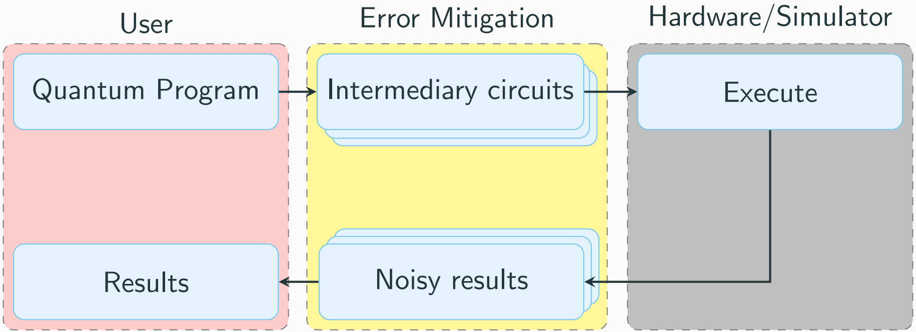




Running quantum programs in practice



Running quantum programs in practice with Mitiq



Let's try Mitiq!

https://github.com/unitaryfund/mitiq-tutorial/

Executors Continued

An executor is anything with a type signature:

$$\texttt{(QPROGRAM -> QuantumResult)}$$

$$\texttt{QPROGRAM} = \cup \cup \cup \cup$$

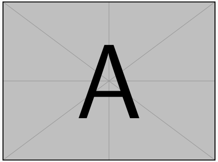
$$\texttt{QuantumResult} = \texttt{float} \cup \texttt{density} \cup \texttt{bitstring}$$

Calibration

Sneak Preview of Part II

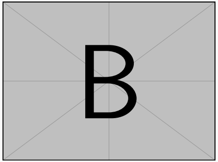
Probabilistic Error Cancellation

Key Idea: Use noisy operations to build up noiseless ones by selective cancellation and sampling.



Digital Dynamical Decoupling

Key Idea: The devil finds work for idle [qubits].



Interested in this work?

OPEN POSITIONS

Community Manager, Full Time, Remote → **MORE INFO**

Member of Technical Staff, Full Time, Remote → **MORE INFO**

Quantum Open Source Fellow, Full Time, Remote → **MORE INFO**

https://unitary.fund/careers/