# Error Mitigation with Mitiq

Nate Stemen

Sep 18, 2023

Unitary Fund

# Follow along!

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

# Experience

1. Who has written a quantum program before?
2. Who has run a quantum program on hardware before?
3. Who has used error mitigation?
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.

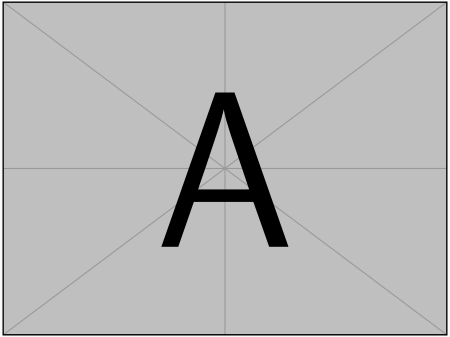
# What is Quantum Error Mitigation?

**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
- . . .

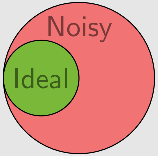


# QEM Methods

## Zero-Noise Extrapolation

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

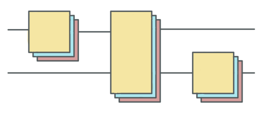
## Symmetry-based techniques



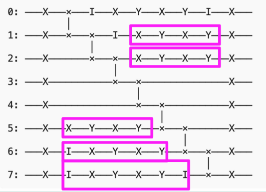

$$M\,|\psi\rangle = |\psi\rangle$$

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

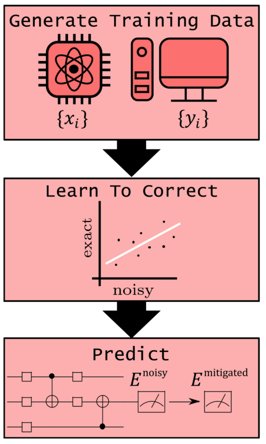
## Probabilistic Error Cancellation



## 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
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- Collect results
- Infer ideal expectation values

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

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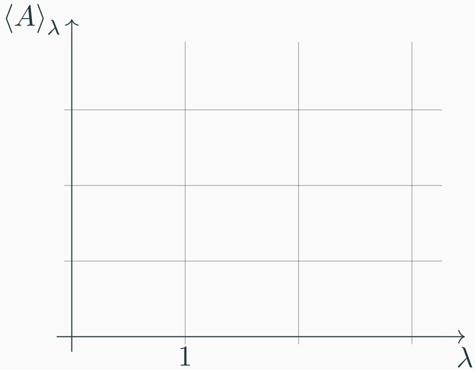

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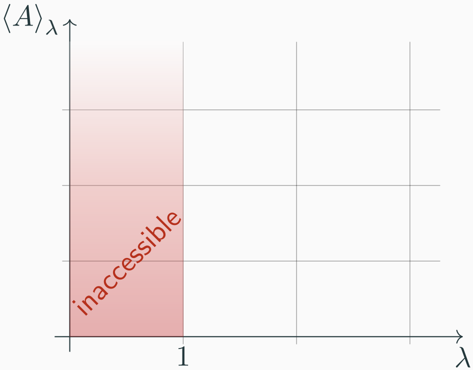

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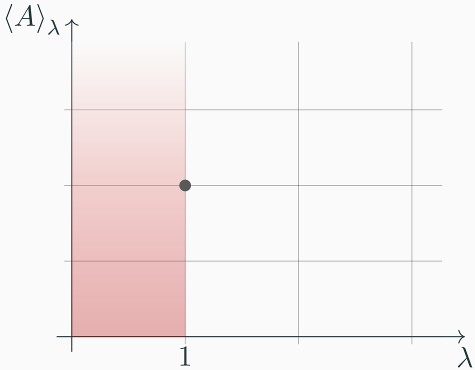

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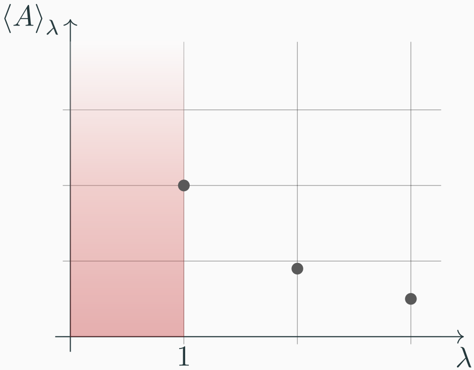

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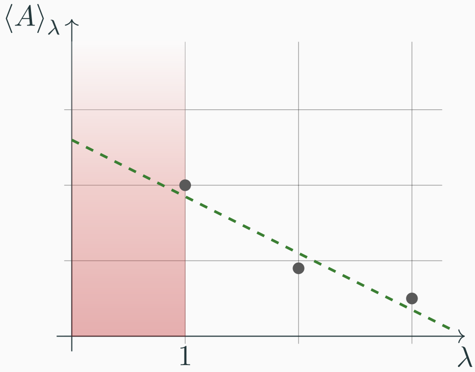

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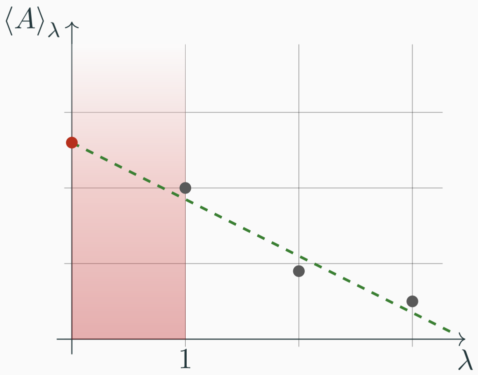

# Zero-Noise Extrapolation (ZNE)

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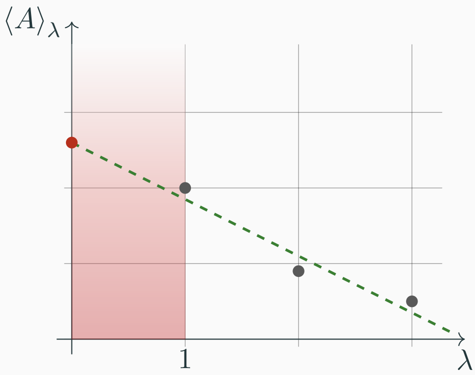

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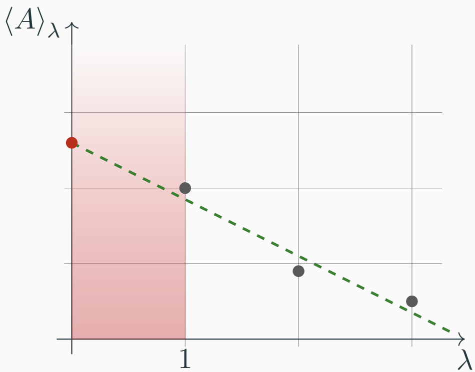


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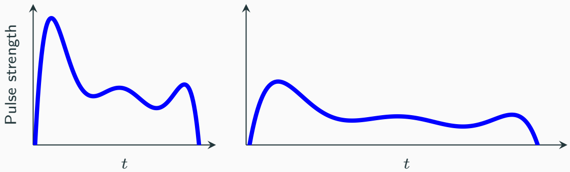


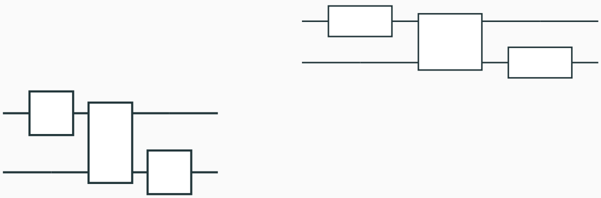

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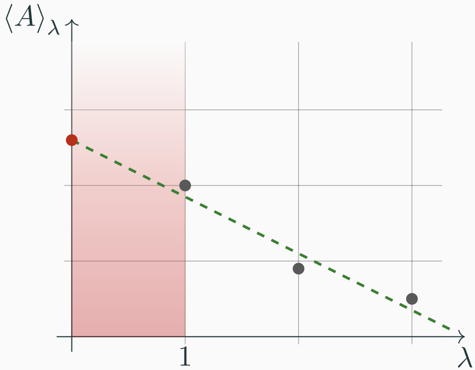
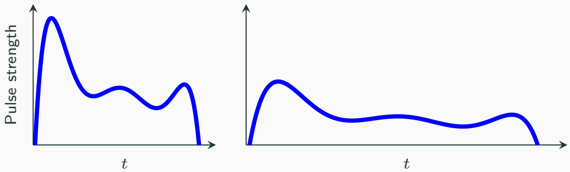
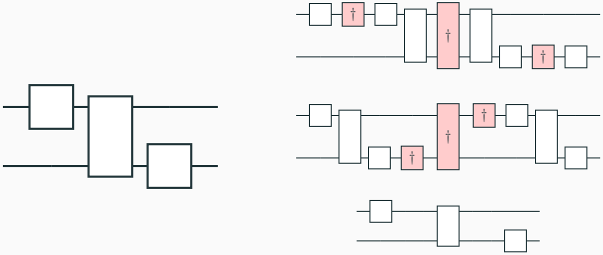
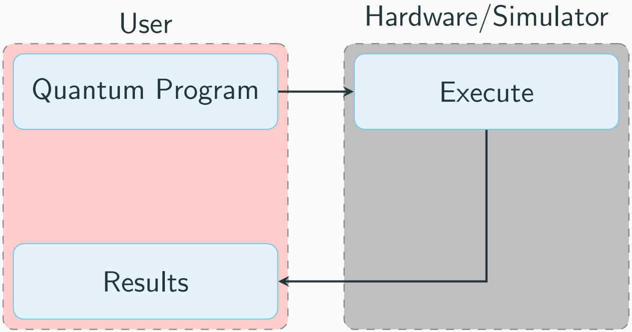


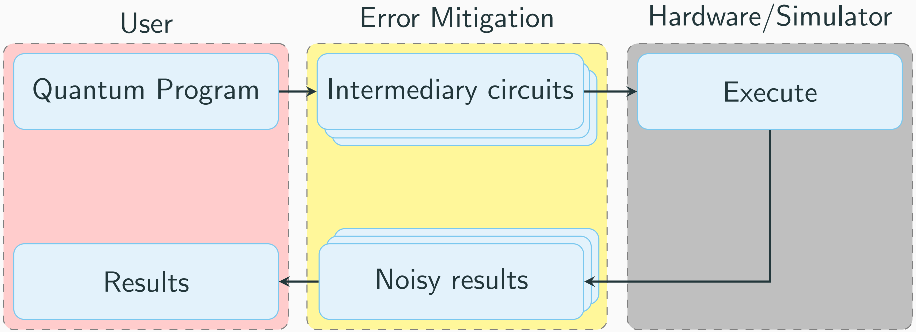



# Running quantum programs in practice



# 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:

`QPROGRAM -> QuantumResult`

$$\mathtt{QPROGRAM} = \mathtt{cirq.Circuit} \cup \mathtt{qiskit.QuantumCircuit} \cup \mathtt{pyquil.Program}$$
$$\mathtt{QuantumResult} = \mathtt{float} \cup \mathtt{density} \cup \mathtt{bitstring}$$

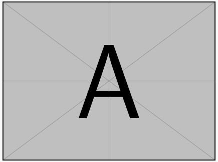
replace circuit names with images

# Calibration

# Sneak Preview of Part II

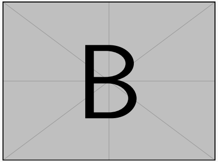
## Probabilistic Error Cancellation

**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/