


Error Mitigation with Mitiq

Part 1: Zero-Noise Extrapolation & Calibration

Nate Stemen & Misty Wahl

Sep 18, 2023





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Mitiq is a Python toolkit for implementing error mitigation techniques on quantum computers.

Current quantum computers are noisy due to interactions with the environment, imperfect gate applications, state preparation and measurement errors, etc. Error mitigation seeks to reduce these effects at the software level by compiling quantum programs in clever ways.

Want to know more? Check out our [documentation](#) and chat with us on [Discord](#).



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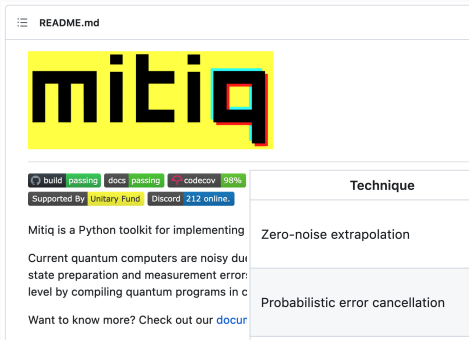
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Mitq is a Python toolkit for implementing

Current quantum computers are noisy due to state preparation and measurement errors. This can be mitigated by compiling quantum programs in a way that minimizes the number of operations and the number of qubits used.

Want to know more? Check out our [docur](#)

| Technique | Documentation | Mitiq module | Paper Reference(s) |
|---|---------------|---------------------------|--|
| Zero-noise extrapolation | ZNE | mitiq.zne | 1611.09301 1612.02058 1805.04492 |
| Probabilistic error cancellation | PEC | mitiq.pec | 1612.02058 1712.09271 1905.10135 |
| (Variable-noise) Clifford data regression | CDR | mitiq.cdr | 2005.10189 2011.01157 |
| Digital dynamical decoupling | DDD | mitiq.ddd | 9803057 1807.08768 |
| Readout-error mitigation | REM | mitiq.rem | 1907.08518 2006.14044 |



```
import cirq

+ import mitiq

qubit = cirq.LineQubit(1)
circuit = cirq.Circuit(cirq.X(qubit) for _ in range(100))

- expval = execute(circuit)
+ expval = mitiq.zne.execute_with_zne(circuit, execute)

print(f"Error: {1 - expval:.3}")

- # Error: 0.244
+ # Error: 0.058
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☰ README.md



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Probabilistic error cancellation

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mitiq.pec

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Digital dynamical decoupling

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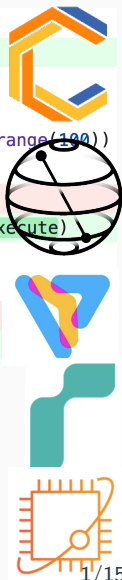
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Follow along!



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

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4. Who has used Mitiq?

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.

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But we still want to use them!

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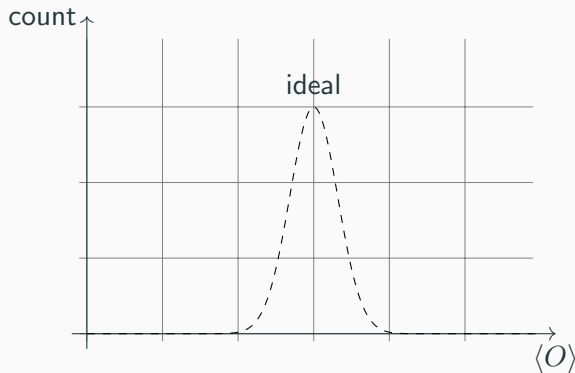
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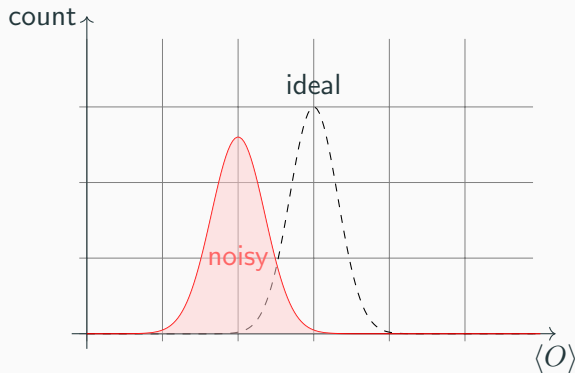


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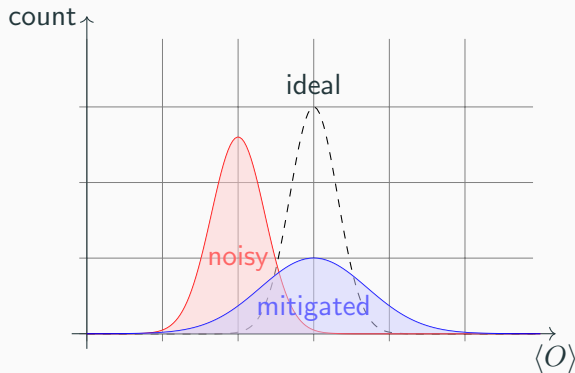


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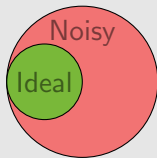
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Zero-Noise Extrapolation

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

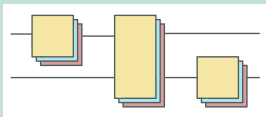
Symmetry-based techniques



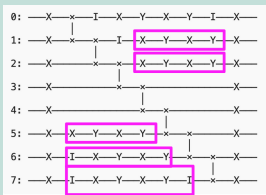
$$M|\psi\rangle = |\psi\rangle$$

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

Probabilistic Error Cancellation

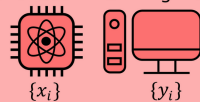


Dynamical Decoupling



Learning- based methods

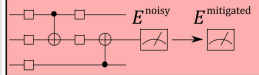
Generate Training Data



Learn To Correct



Predict



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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- Collect results
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Key Idea

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

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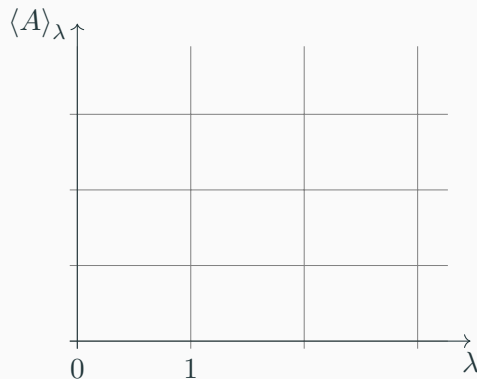
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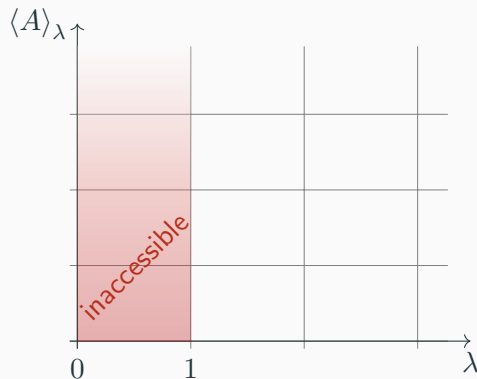


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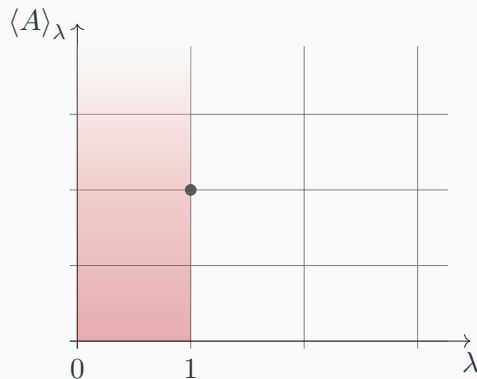


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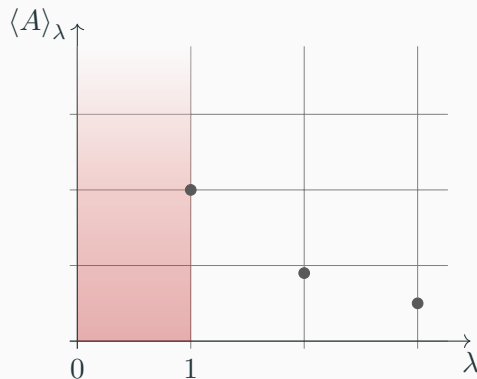


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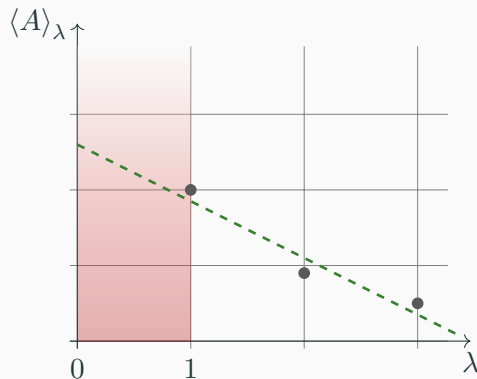


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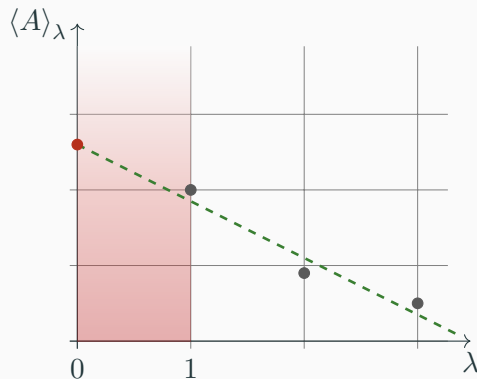


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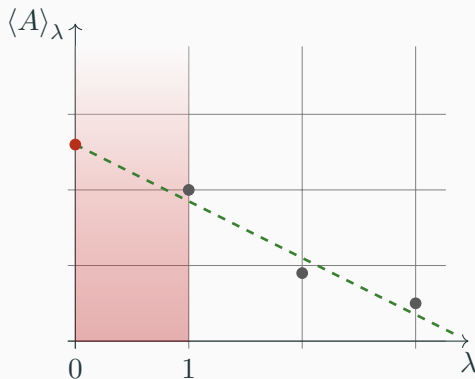
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How do we scale the noise **up**?

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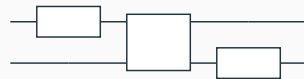
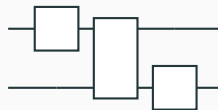
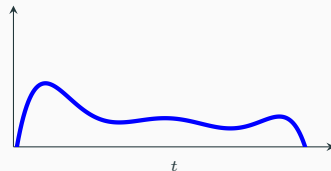
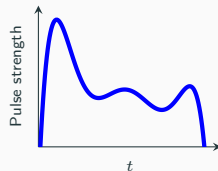
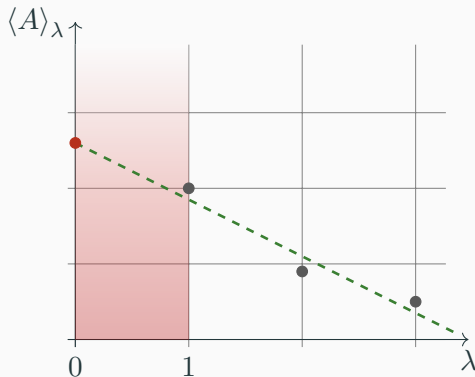
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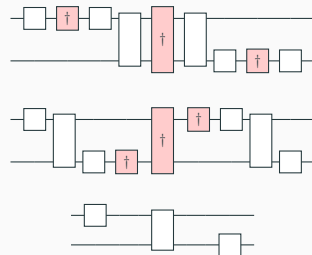
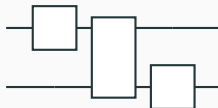
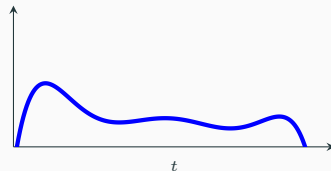
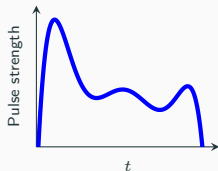
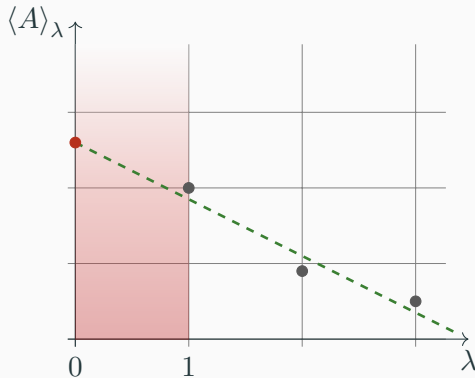
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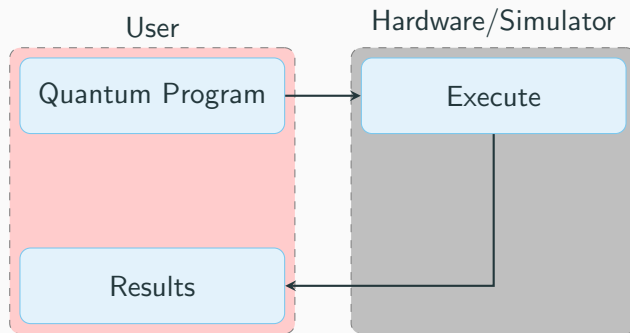
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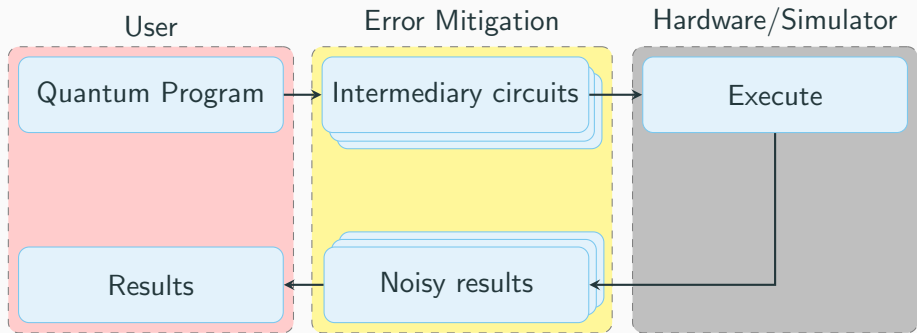
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Running quantum programs in practice



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)`

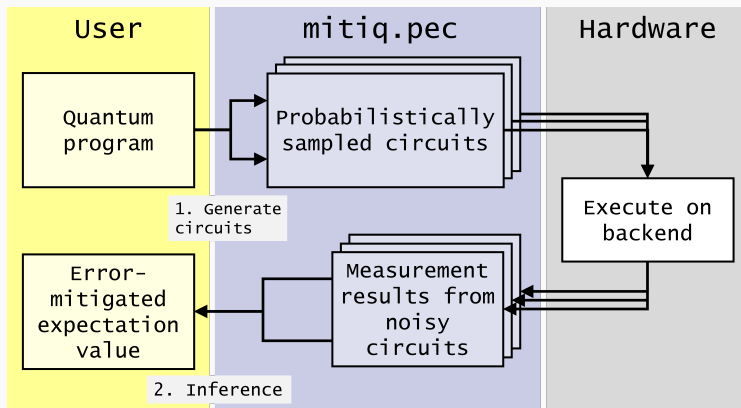


`QuantumResult = float \cup density \cup bitstring`

Sneak Preview of Part II

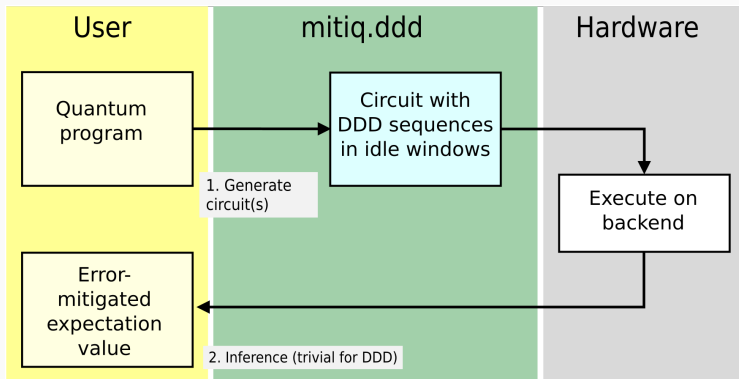
Probabilistic Error Cancellation

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?

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Quantum Open Source Fellow, Full Time, Remote → [MORE INFO](#)



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