

Error Mitigation with Mitiq


Quantum Research & Industry Skills Exchange 2024

Nate Stemen

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March 13, 2024





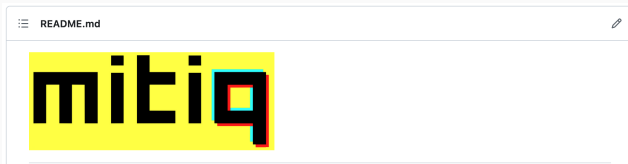
build passing docs passing codecov 98% pypi package 0.29.0 arXiv 2009.04417 Downloads 100k GitHub

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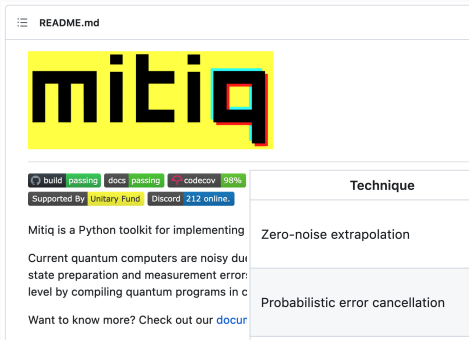
Mitiq is a Python toolkit for implementing error mitigation techniques on quantum computers.

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](#).



Technique	Documentation	Mitq 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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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 gates and measurements.

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

Technique

Zero-noise extrapolation

Probabilistic error cancellation

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mitiq.pec

1712.09271
1905.10135

(Variable-noise) Clifford data regression

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Digital dynamical decoupling

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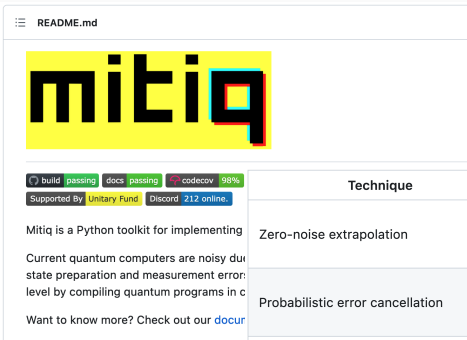
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4. Who has used Mitiq?

1. Understand context, and general goal of quantum error mitigation.
2. Understand the main ideas behind Zero-Noise Extrapolation (ZNE) and Digital Dynamical Decoupling (DDD).
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!

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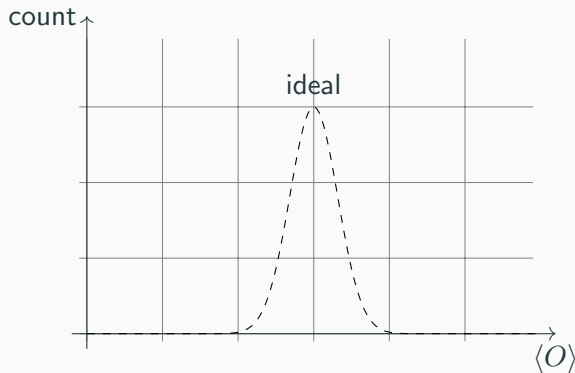
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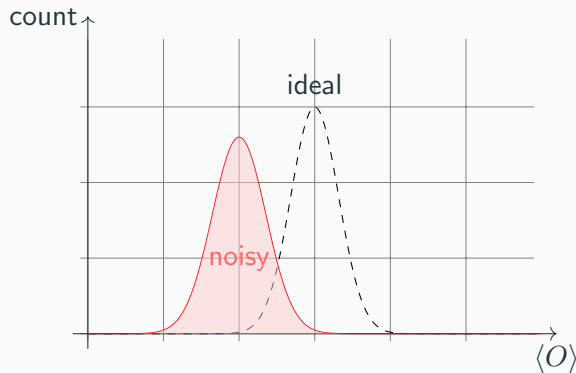


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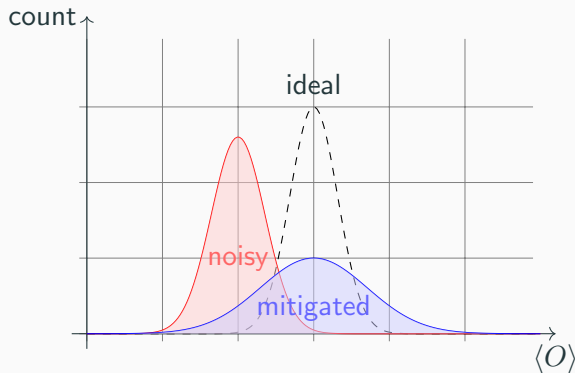


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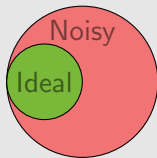
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Zero-Noise Extrapolation

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

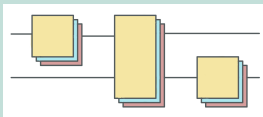
Symmetry-based techniques



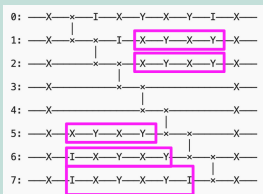
$$M|\psi\rangle = |\psi\rangle$$

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

Probabilistic Error Cancellation

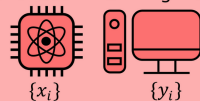


Dynamical Decoupling

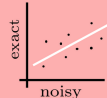


Learning- based methods

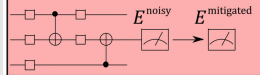
Generate Training Data



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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Key Idea

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

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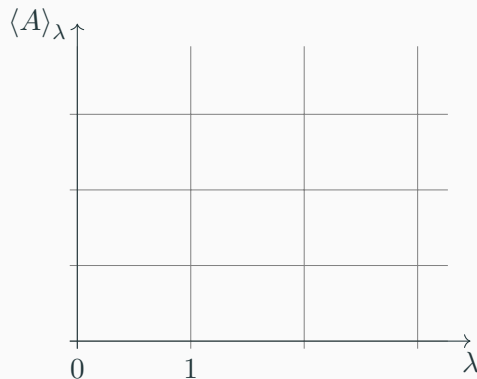
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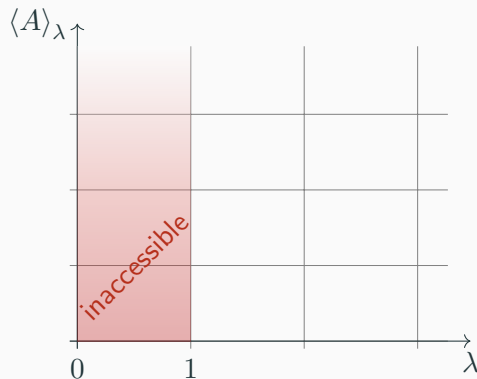


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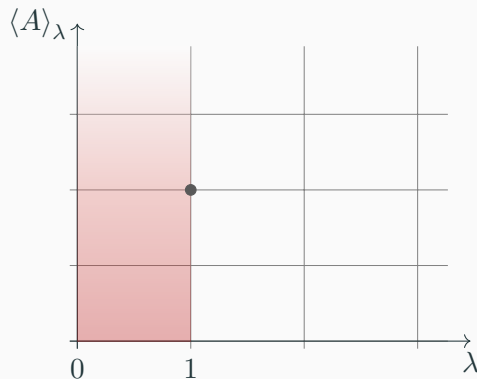


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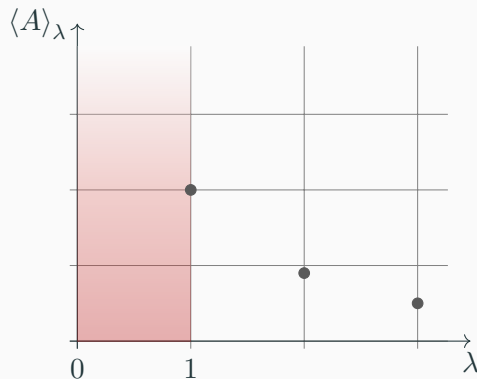


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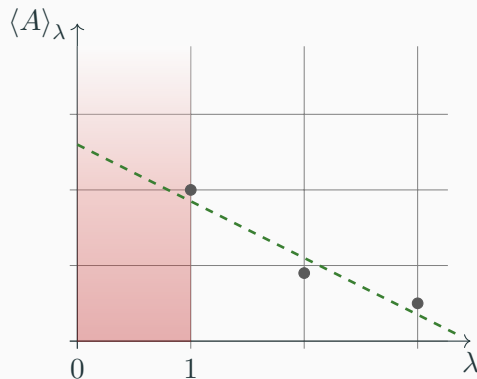


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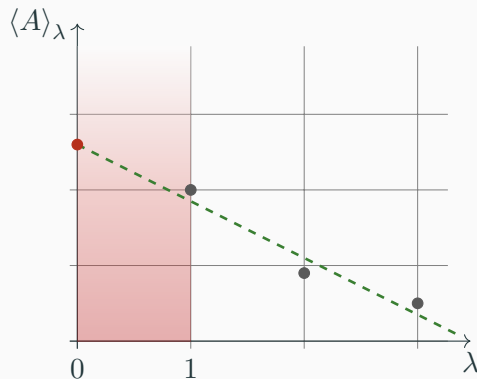


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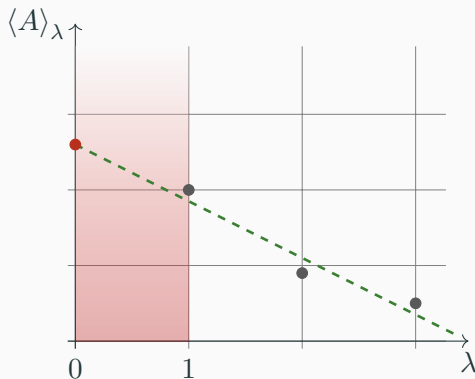
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How do we scale the noise **up**?

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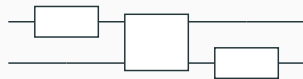
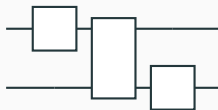
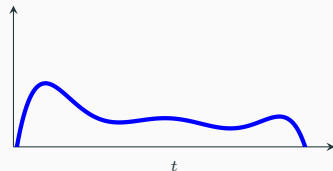
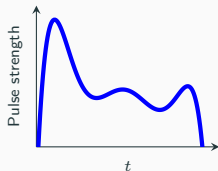
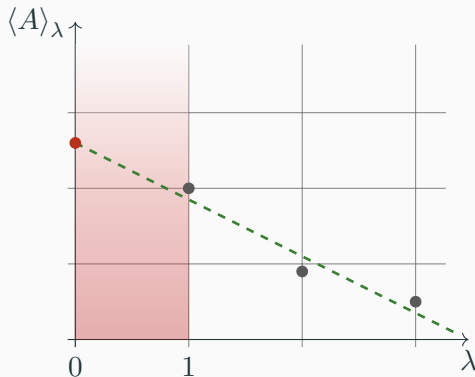
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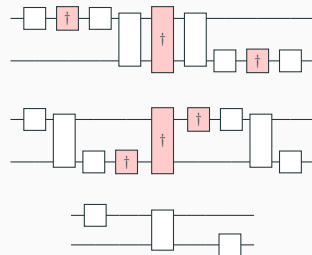
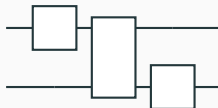
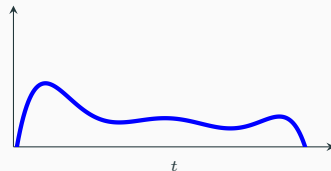
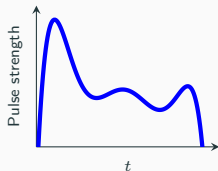
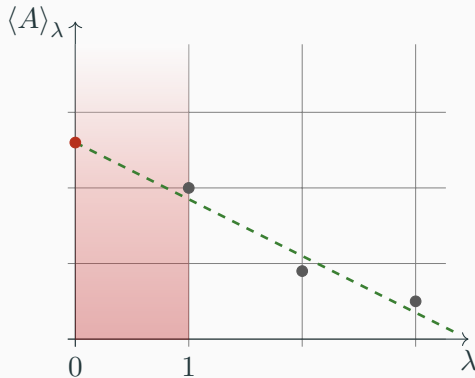
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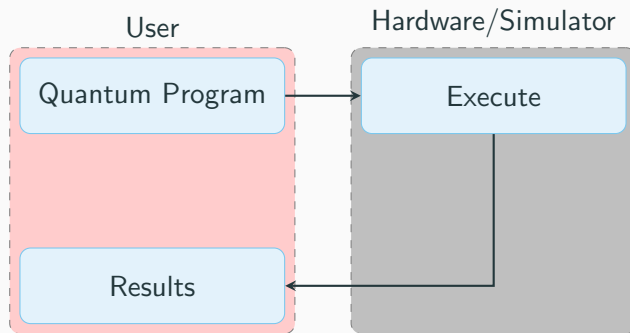
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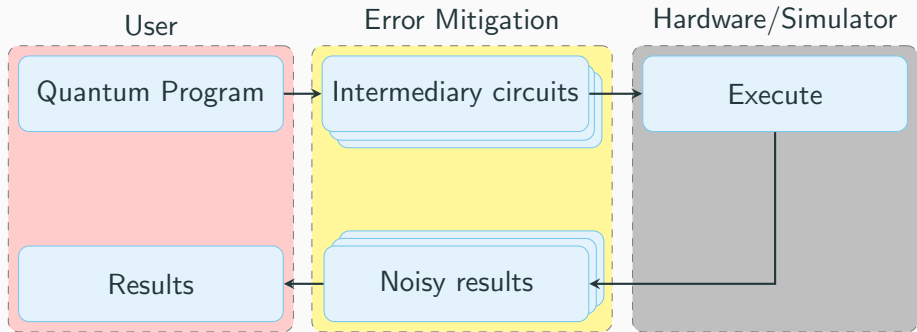
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Running quantum programs in practice



Running quantum programs in practice with Mitiq



Let's try Mitiq!

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