


# Error Mitigation with Mitiq

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Nate Stemen

Sep 18, 2023





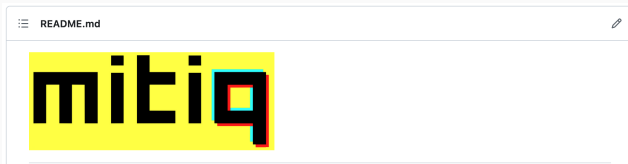
build passing docs passing codecov 98% pypi package 0.29.0 arXiv 2009.04417 Downloads 100k GitHub

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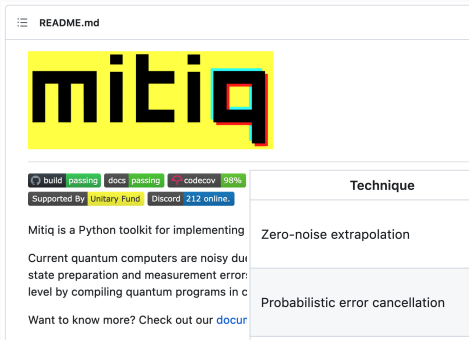
Mitiq is a Python toolkit for implementing error mitigation techniques on quantum computers.

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	<a href="#">ZNE</a>	<a href="#">mitiq.zne</a>	<a href="#">1611.09301</a> <a href="#">1612.02058</a> <a href="#">1805.04492</a>
Probabilistic error cancellation	<a href="#">PEC</a>	<a href="#">mitiq.pec</a>	<a href="#">1612.02058</a> <a href="#">1712.09271</a> <a href="#">1905.10135</a>
(Variable-noise) Clifford data regression	<a href="#">CDR</a>	<a href="#">mitiq.cdr</a>	<a href="#">2005.10189</a> <a href="#">2011.01157</a>
Digital dynamical decoupling	<a href="#">DDD</a>	<a href="#">mitiq.ddd</a>	<a href="#">9803057</a> <a href="#">1807.08768</a>
Readout-error mitigation	<a href="#">REM</a>	<a href="#">mitiq.rem</a>	<a href="#">1907.08518</a> <a href="#">2006.14044</a>



```
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
```

Technique			
Zero-noise extrapolation	<pre>print(f"Error: {1 - expval:.3}") - # Error: 0.244 + # Error: 0.058</pre>		
Probabilistic error cancellation	PEC	<code>mitiq.pec</code>	1712.09271 1905.10135
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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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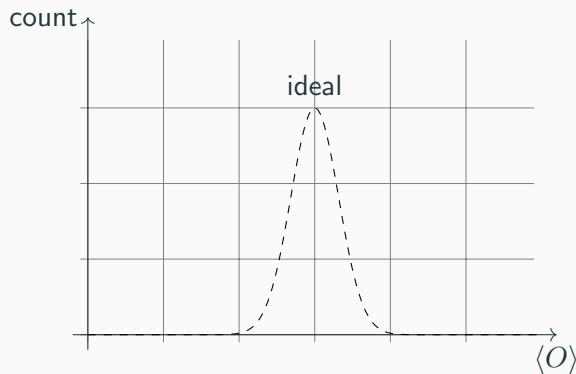
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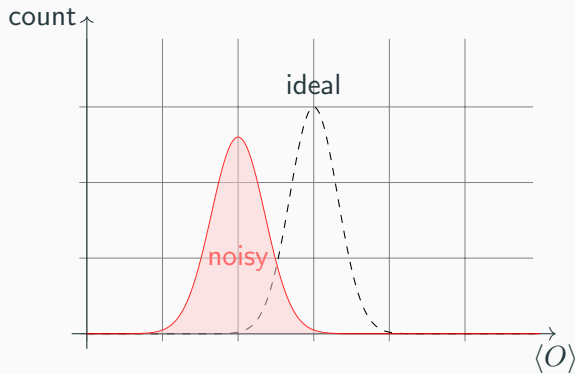


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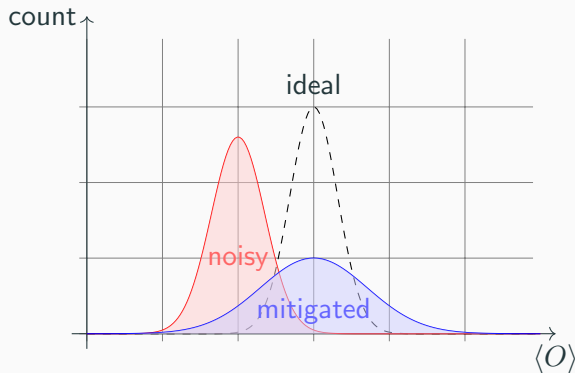


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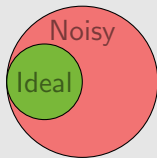
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## Zero-Noise Extrapolation

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

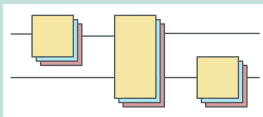
## Symmetry-based techniques



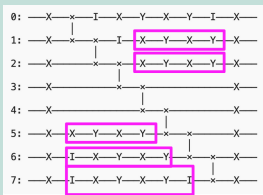
$$M|\psi\rangle = |\psi\rangle$$

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

## Probabilistic Error Cancellation

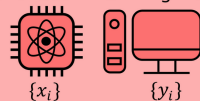


## Dynamical Decoupling



## Learning- based methods

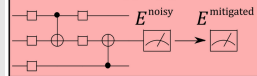
Generate Training Data



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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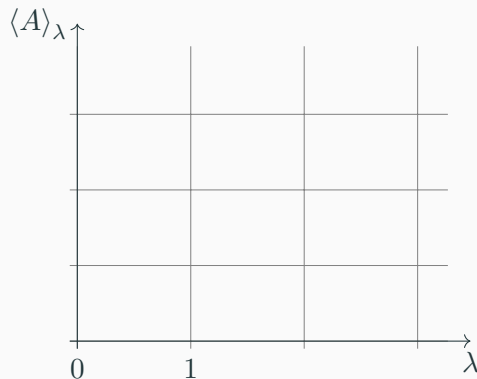
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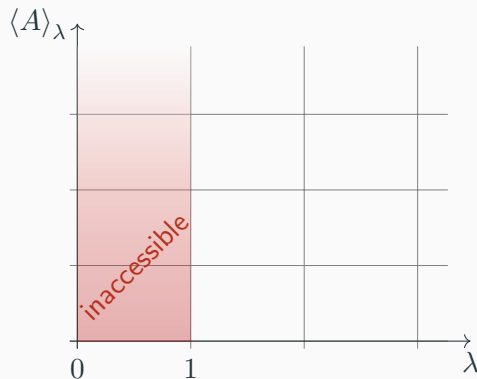


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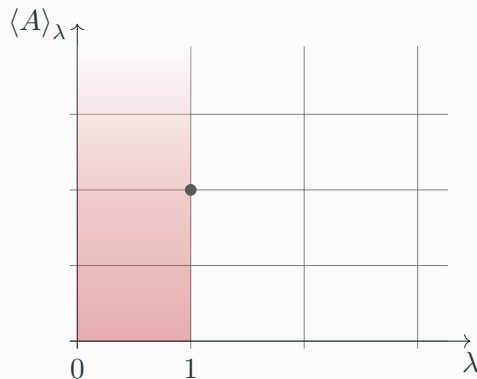


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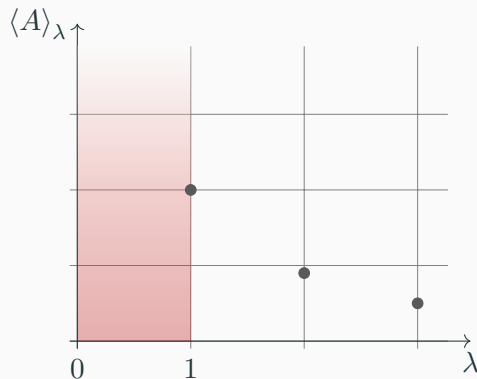


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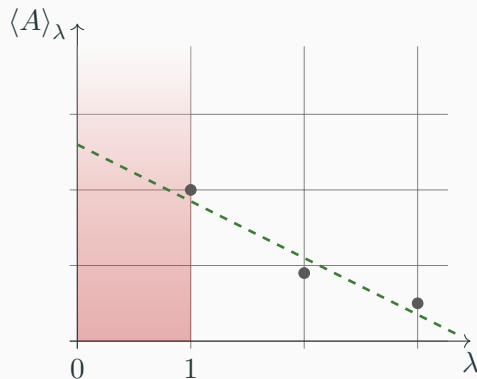


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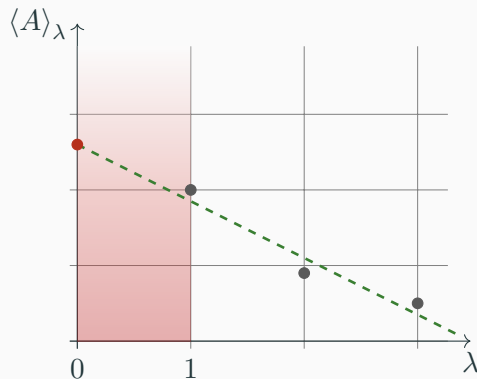


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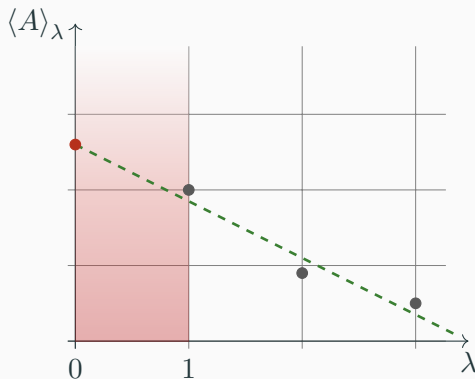
# Zero-Noise Extrapolation (ZNE)

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

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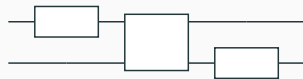
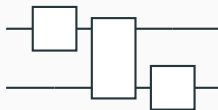
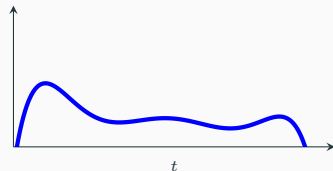
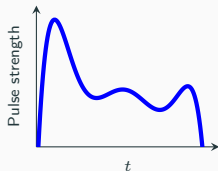
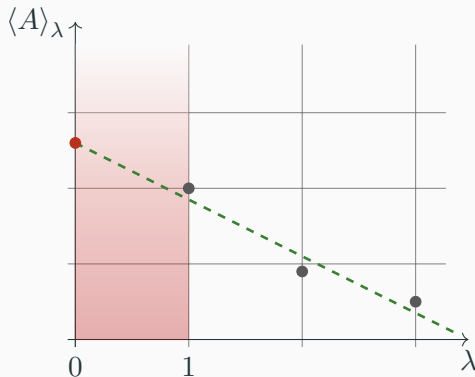
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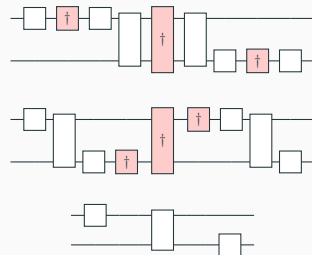
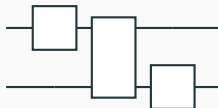
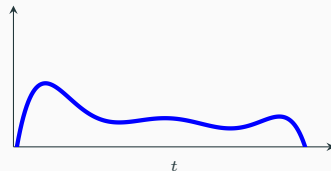
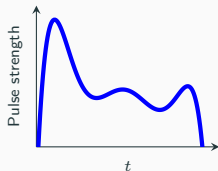
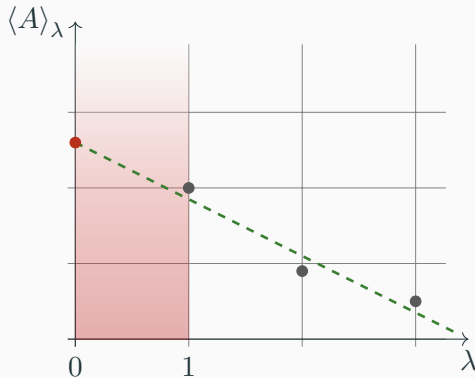
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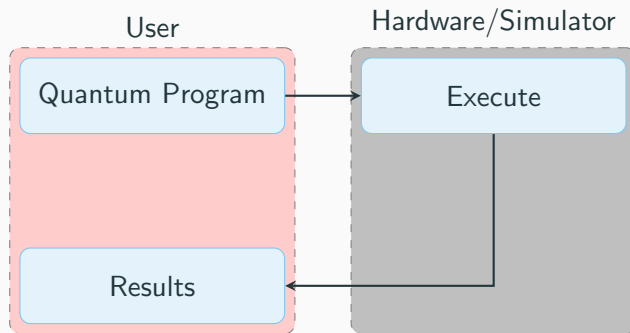
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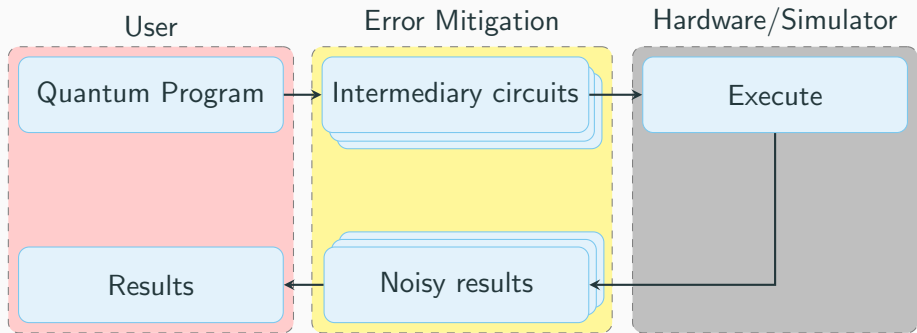
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# Running quantum programs in practice



# 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

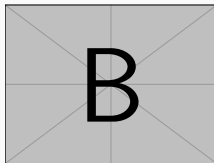
### Probabilistic Error Cancellation

**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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