Error Mitigation with Mitiq

Nate Stemen

Sep 18, 2023

Unitary Fund

TEAM Tough Errors Are No Match

Mitiq

README.md

build passing | docs passing | codecov 98% | pypi package 0.29.0 | arXiv 2009.04417 | Downloads 106k | 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.

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Mitiq is a Python toolkit for implementing

Current quantum computers are noisy due
state preparation and measurement errors
level by compiling quantum programs in c

Want to know more? Check out our docum

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

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```diff
  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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Follow along!

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

Experience

1. Who has written a quantum program 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.

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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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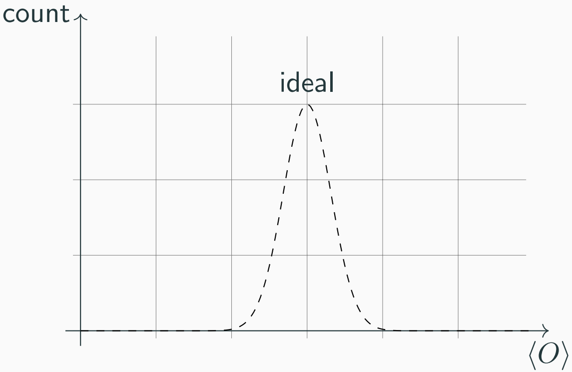

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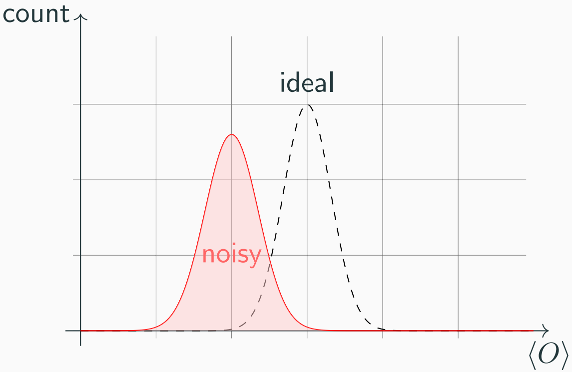

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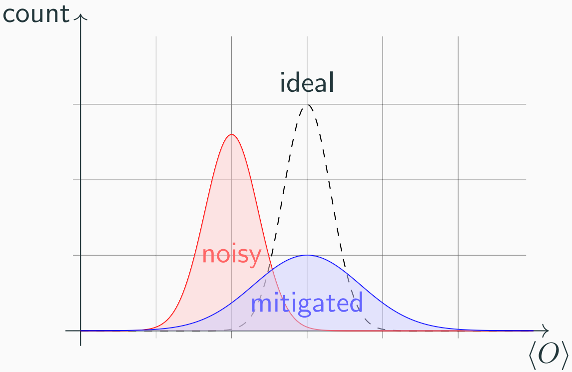
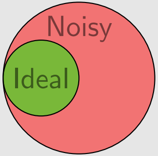


QEM Methods

Zero-Noise Extrapolation

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

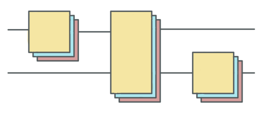
Symmetry-based techniques



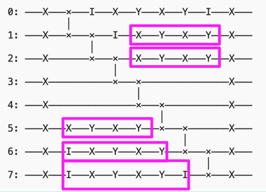
$$M \left|\psi\right\rangle = \left|\psi\right\rangle$$

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

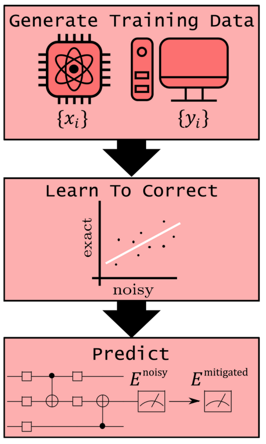
Probabilistic Error Cancellation



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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- 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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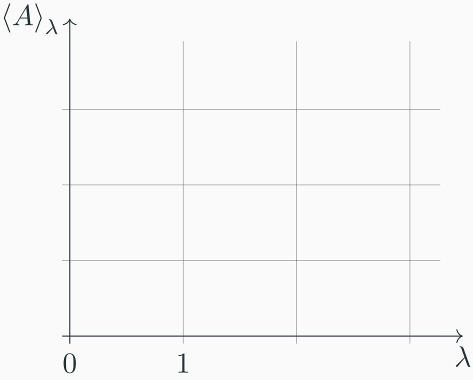

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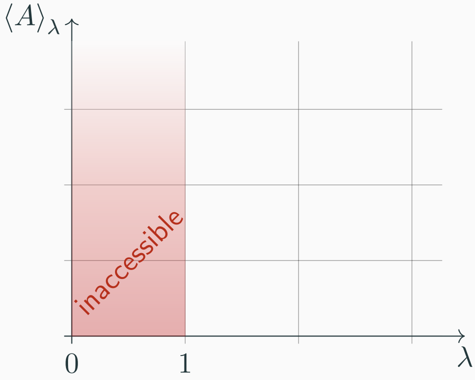

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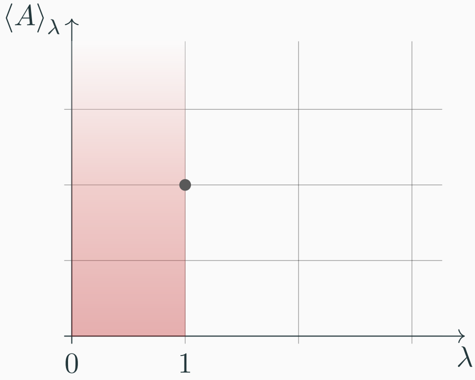

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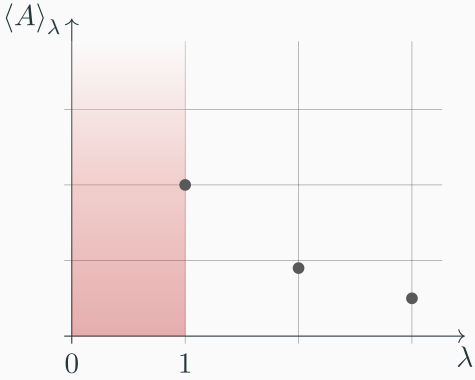

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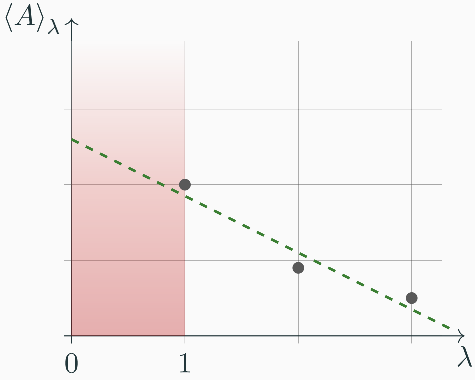

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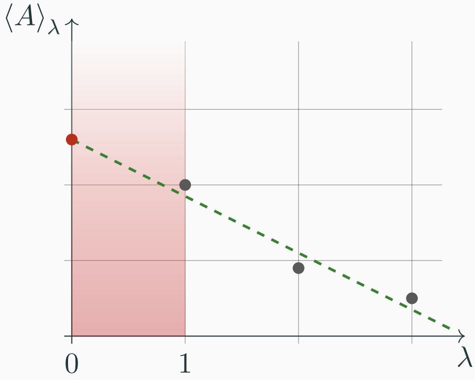

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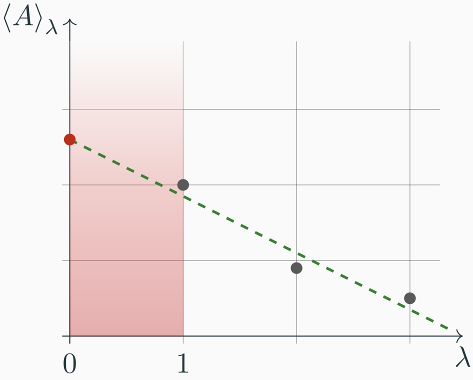

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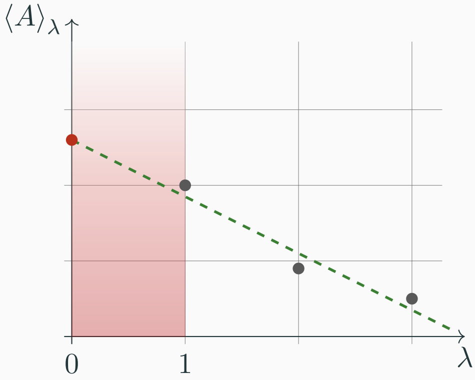

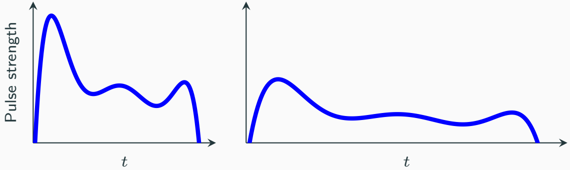

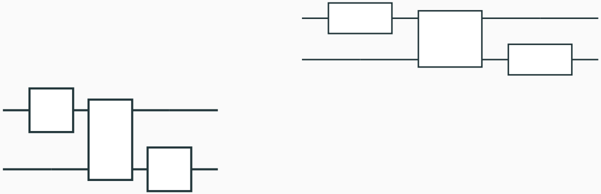

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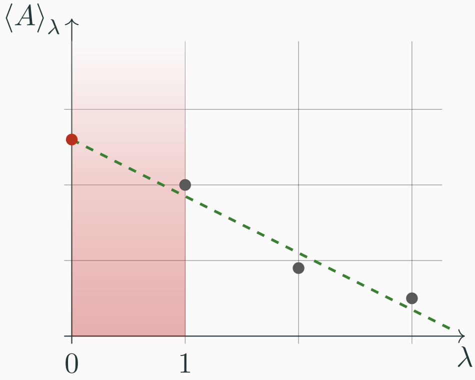

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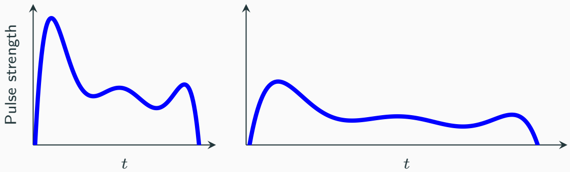
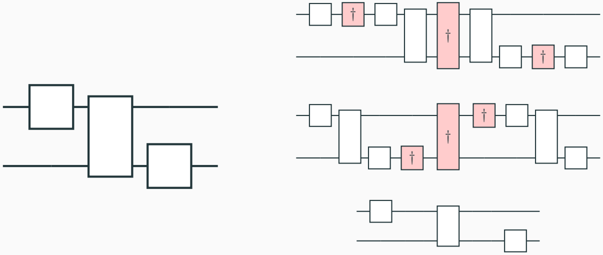
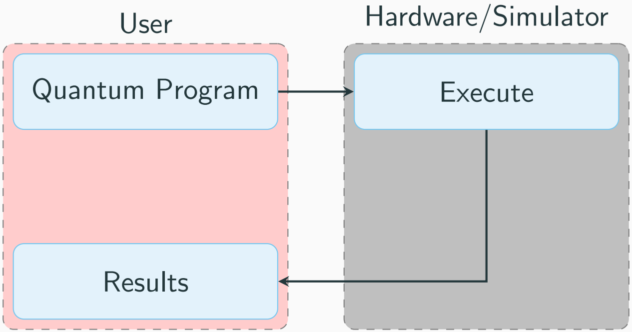
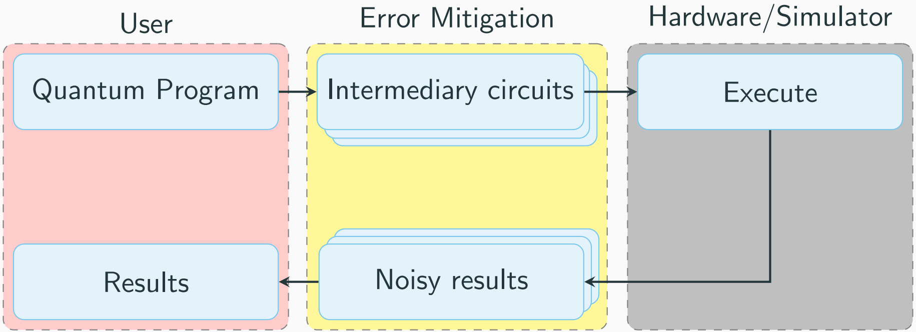




Running quantum programs in practice



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)
```

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

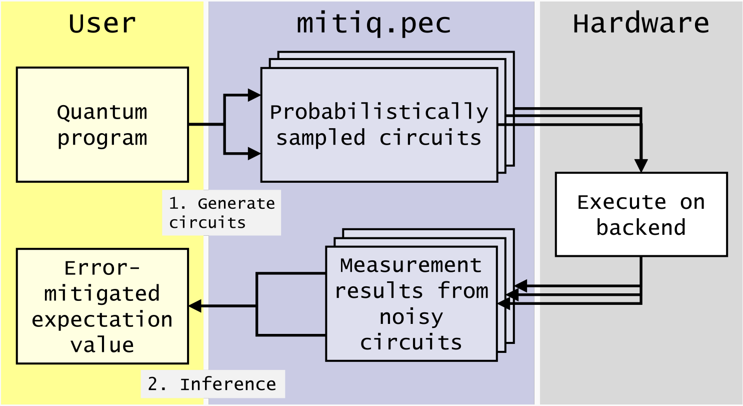
$\texttt{QuantumResult} = \texttt{float} \cup \texttt{density} \cup \texttt{bitstring}$

Calibration

Sneak Preview of Part II

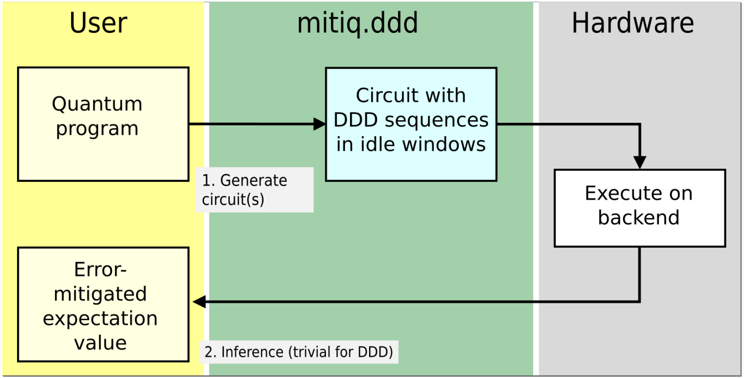
Probabilistic Error Cancellation

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].



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

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

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