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# QAGC : VQE with Frugal Optimization

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# Outline

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**01** Strategy

**02** Optimizer

**03** ZNE

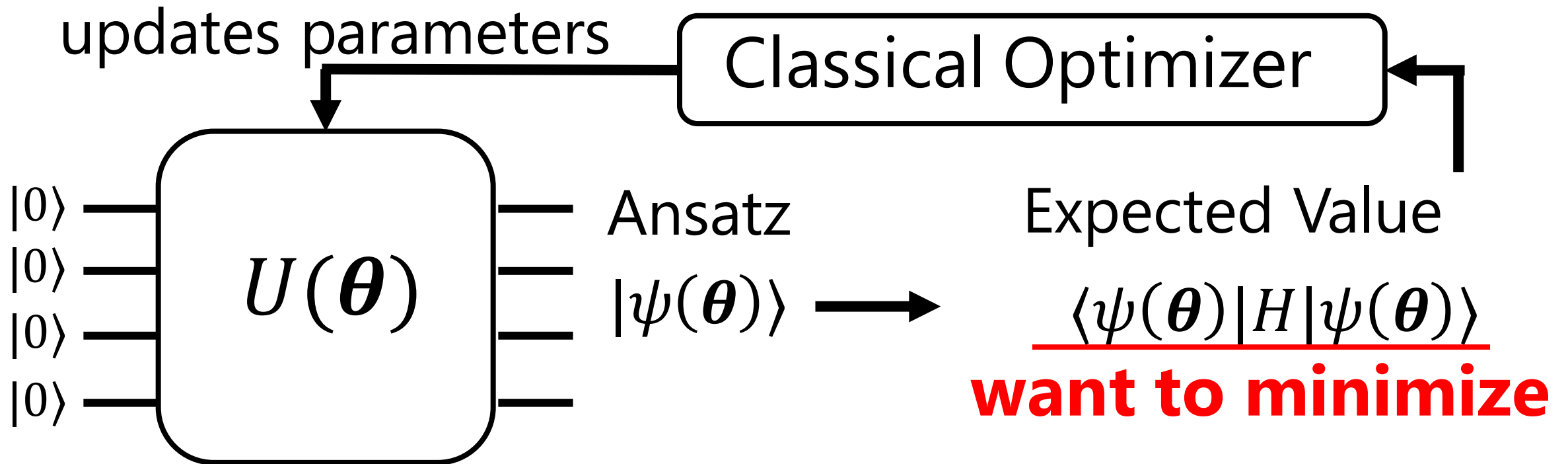
**04** Conclusion



01

Strategy

# What is the VQE?



**How can we find the best parameters?**

# Limitations and Strategies

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- **Noise** 

- NISQ device has critical noise for computation

- **selection of device & ZNE**

- **Execution Time** 

- In this challenge, we had to reduce execution time

- **low-cost optimizer & stochastic shots allocator**



02

Optimizer

# SPSA Optimizer

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## Simultaneous Perturbation Stochastic Approximation

gradient prediction:  $\hat{g}(\boldsymbol{\theta}_k) = \frac{f(\boldsymbol{\theta}_k + c_k \boldsymbol{\Delta}) - f(\boldsymbol{\theta}_k - c_k \boldsymbol{\Delta})}{2c_k} \boldsymbol{\Delta}$

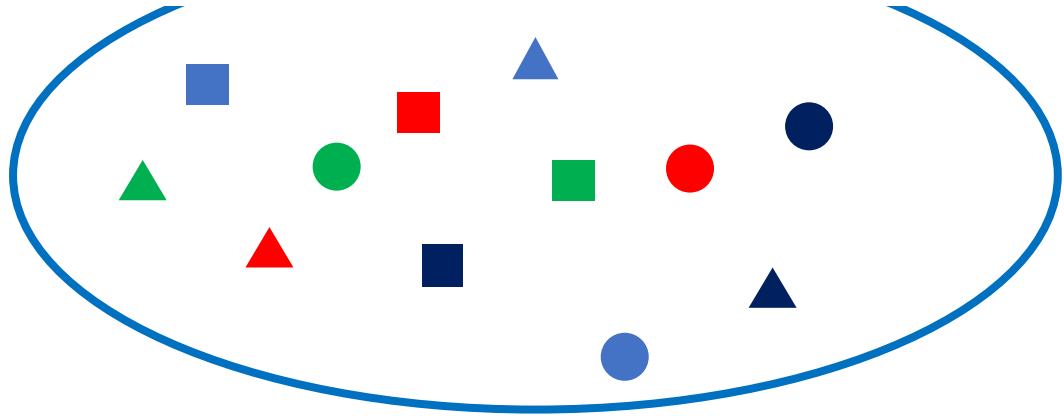
parameters update:  $\boldsymbol{\theta}_{k+1} = \boldsymbol{\theta}_k - a_k \hat{g}(\boldsymbol{\theta}_k)$

**Only need two execution!**

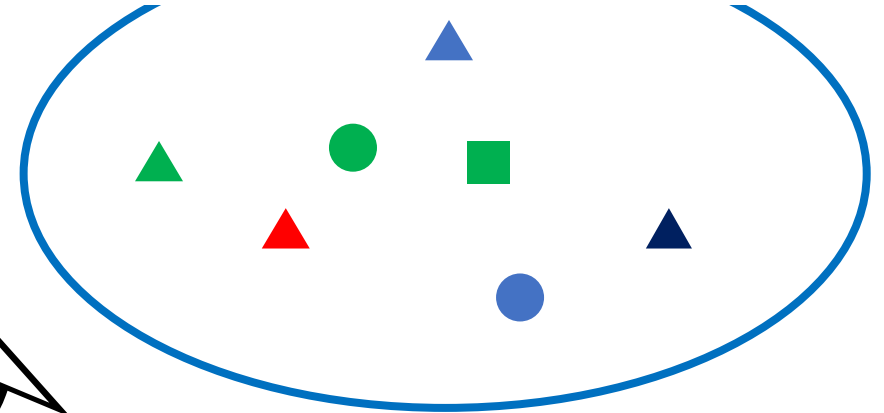
# Stochastic Shots Allocator(SSA)

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Pauli terms of Hamiltonian



measured Pauli terms



stochastic selection



**Reduction of execution time**



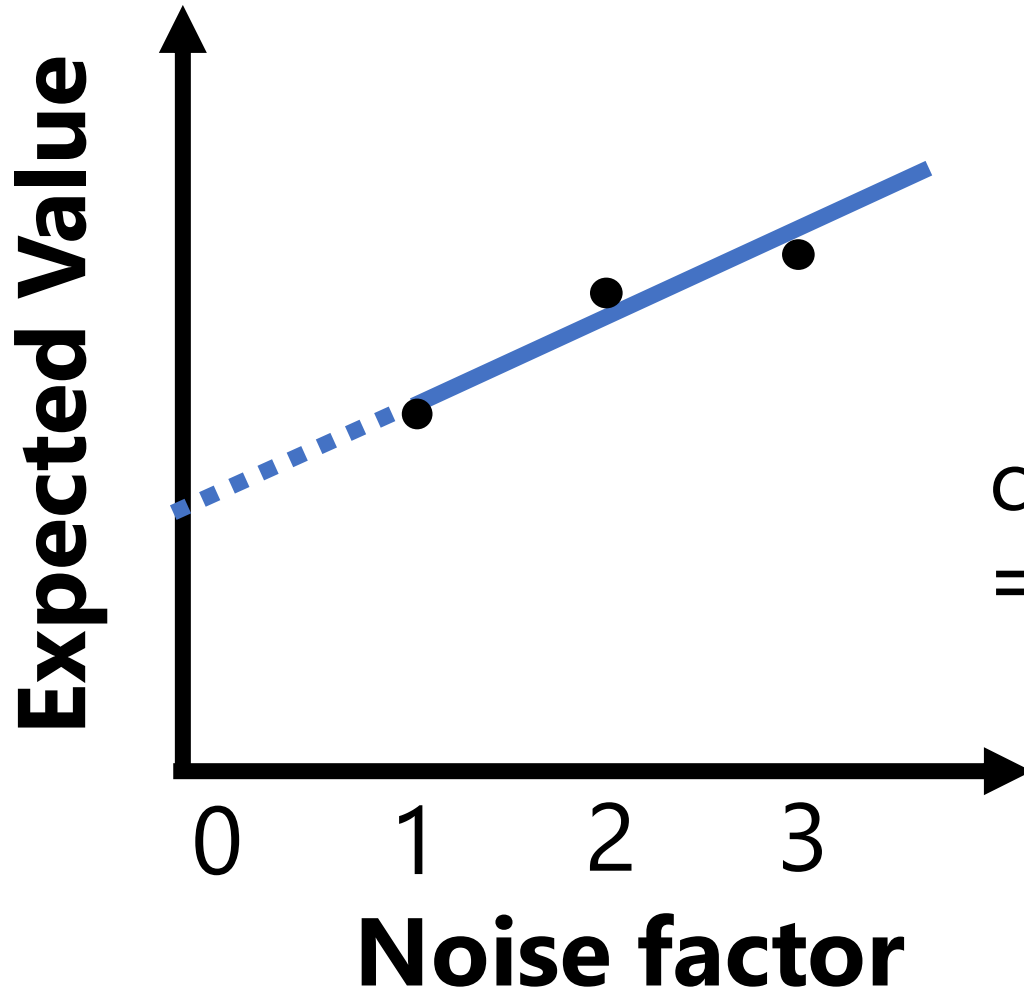


03

ZNE

# Zero-Noise Extrapolation

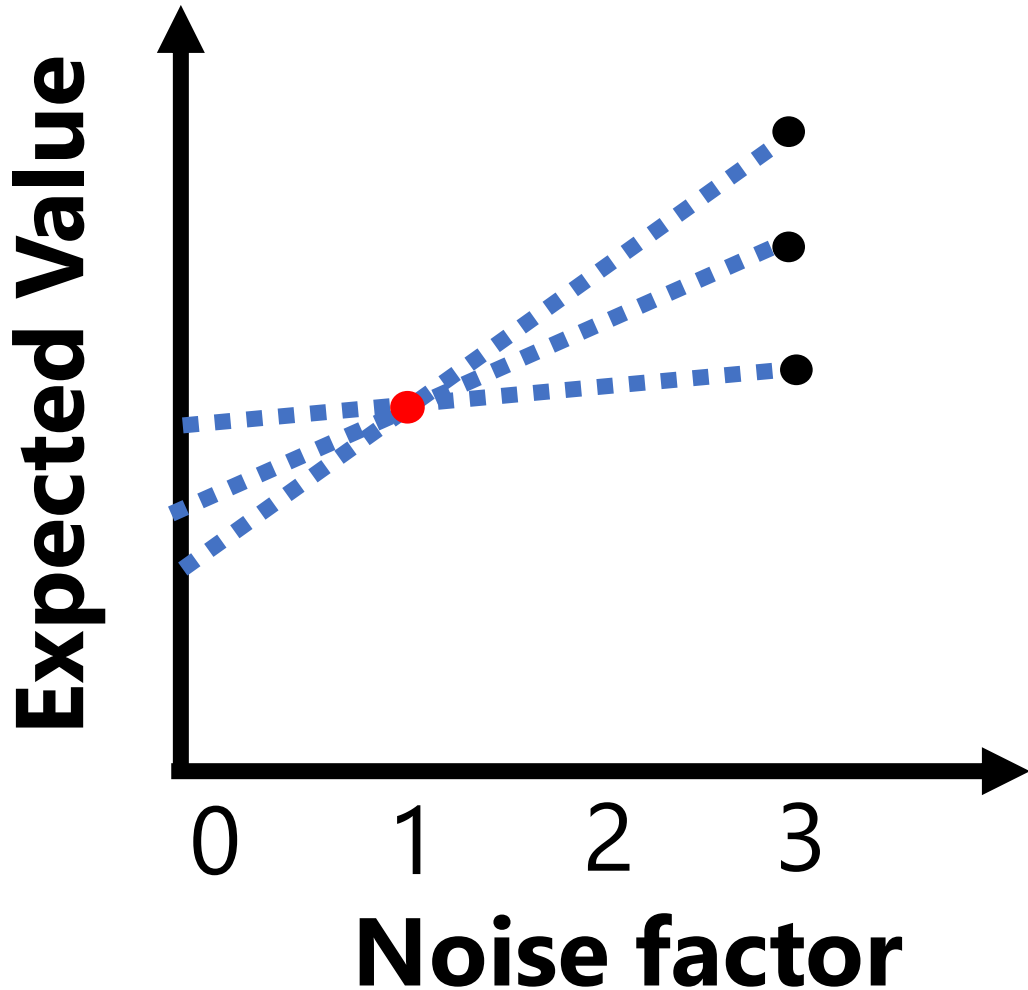
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The method to mitigate noise

computing the value of a noisier circuits  
⇒ extrapolate zero-noise value

# Robust ZNE



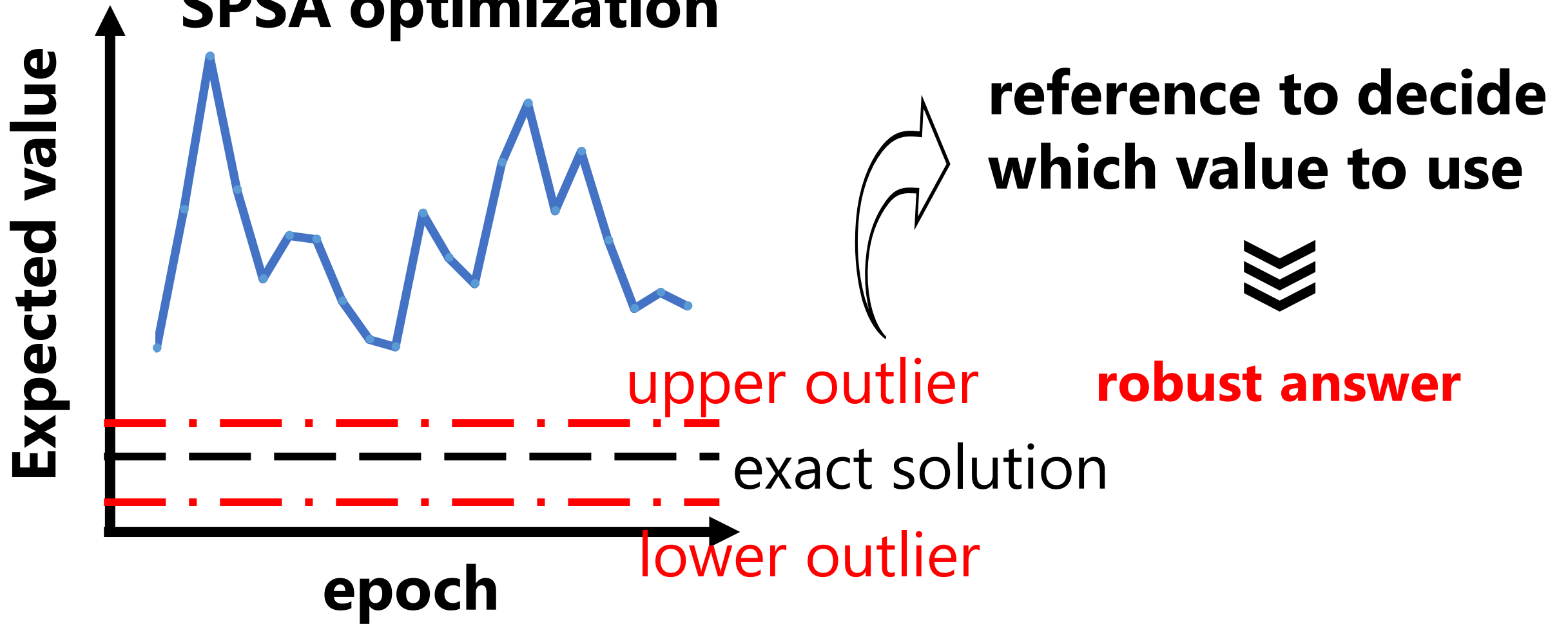
- use the value during optimization
- calculate with a noisier circuit



obtain the three candidates  
of expected value

# Robust ZNE

## SPSA optimization





04

Conclusion

# Conclusion

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**SPSA**

**SSA**

**ZNE**

**Frugal Optimization**

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graph TD; SPSA((SPSA)) --- Line; SSA((SSA)) --- Line; ZNE((ZNE)) --- Line; Line --- FO[Frugal Optimization];
```

The diagram illustrates the concept of Frugal Optimization. It features three blue circles at the top, each containing a white acronym: SPSA on the left, SSA in the center, and ZNE on the right. A thick black horizontal line connects the bottom of these three circles. From the center of this line, a black arrow points downwards to a blue rectangular box containing the text 'Frugal Optimization' in yellow.

# References

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- [1] James C. Spall, "An Overview of the Simultaneous Perturbation Method for Efficient Optimization", 1998
- [2] T. Giurgica-Tiron, Y. Hindy, R. LaRose, A. Mari, W. J. Zeng , " Digital zero noise extrapolation for quantum error mitigation", IEEE International Conference on Quantum Computing and Engineering ,2020
- [3] PennyLane, "Frugal shot optimization with Rosalin", [https://pennylane.ai/qml/demos/tutorial\\_rosalin](https://pennylane.ai/qml/demos/tutorial_rosalin), viewed 22 July 2023