High Energy Physics and Quantum Computing

2024 IonQ 1st week meeting

Multi-variable integration with a variational quantum circuit

Reference [1]

Juan M. Cruz-Martinez[1], Matteo Robbiati[1,2], and Stefano Carrazza[1,2,3]

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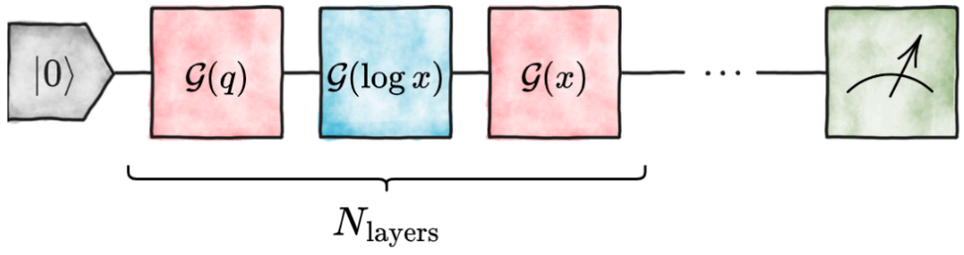
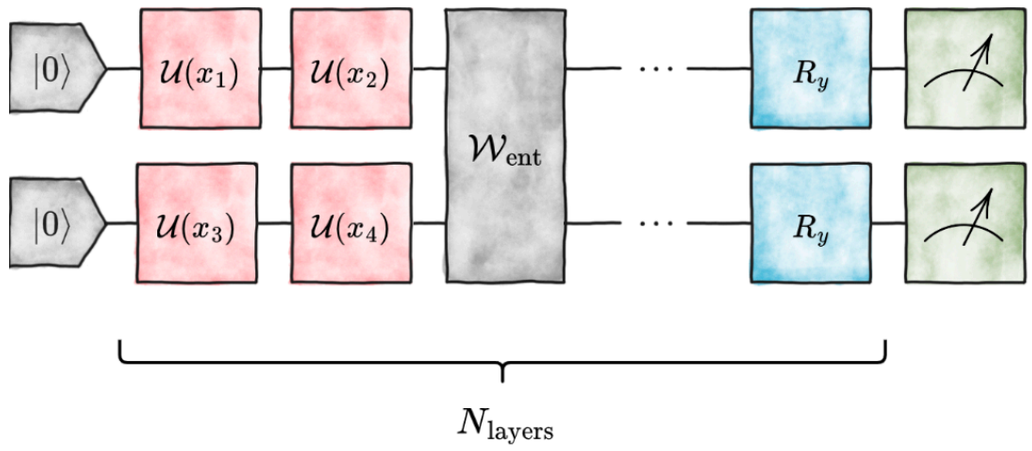
[3]Quantum Research Center, Technology Innovation Institute, Abu Dhabi, UAE.

- This reference introduces a variational quantum circuit for multi-variable integration.

- The study takes advantage of data-reuploading and the parameter shift rule techniques.





- Authors illustrated their idea with two simple examples using the implementation of their idea in **Qibo**.
  - toy example for 3 dim integration involving cosine functions
  - physics example for 2 dim integration with parton distribution functions)

Our short-term goals are

- to implement the ideas in the reference [1] using Qiskit and/or PennyLane,
- to use our implementation for a physics example
- to investigate potential improvements by *adopting different cost functions and designing different circuits*.

Our long-term goal is

- to develop a variational quantum circuit for **importance sampling** and apply the circuit for physics problems.

Importance sampling for stochastic quantum simulations

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Reference [2]

Weekly goal

[Week 1] Review the reference [1] thoroughly and understand basic idea.

[Week 2] Implement the idea using Qiskit and/or PennyLane, and reproduce their results for two examples in the paper.

[Week 3] Then consider a more complex and more realistic example, taking electron-positron production at the Large Hadron Collider (pp → e+e–). Effectively, this problem involves four-dimensional integration.

[Week 4] Try to optimize the circuits with different choice of the cost function or variations of quantum circuits.

[Week 5] Study Monte-Carlo sampling with above integration method, and how to implement the importance sampling into a variational quantum circuit. (Check Ref. [2])

Weekly goal

[Week 1] Review the reference [1] thoroughly and understand basic idea.

[Week 2] Implement the idea using Qiskit and/or PennyLane, and reproduce their results for two examples in the paper.

- (Minor) Matching the paper's results for implementation using other packages requires understanding and emulating the computational setup used in the original experiments.

[Week 3] Then consider a more complex and more realistic example, taking electron-positron production at the Large Hadron Collider (pp → e+e–). Effectively, this problem involves four-dimensional integration.

[Week 4] Try to optimize the circuits with different choice of the cost function or variations of quantum circuits.

[Week 5] Study Monte-Carlo sampling with above integration method, and how to implement the importance sampling into a variational quantum circuit. (Check Ref. [2])

- The biggest unknown is how to introduce the importance sampling into a variational quantum circuit.