Usage Report for Fiscal Year 2022

Project Title:

Deep Learning of Quantum Matrix Models

Name:
○Enrico Rinaldi (1,2), Farad Khoyratee (1)

Laboratory at RIKEN:
(1) Cluster for Pioneering Research, Theoretical Quantum Physics Laboratory
(2) RIKEN Center for Quantum Computing, Quantum Information Physics Theory Research Team

1. Background and purpose of the project, relationship of the project with other projects

Quantum computing and deep learning are two emergent technologies making waves in the computational physics landscape.
In quantum physics we are often interested in computing the wave function of a collection of degrees of freedom to represent, for example, the state of a material, a group of molecules, or a theory of elementary particles.
This wavefunction contains some structure dictated by the physics of the system and can be approximated using neural networks or using quantum circuits.
This project is connected to quantum information science and quantum gravity, because we study the wavefunction of a system of matrices representing a dual theory of gravity in a quantum regime.

2. Specific usage status of the system and calculation method

We have used Hokusai BIGWATERFALL to extend our previous publication on PRX Quantum which was also highlighted in RIKEN Research Highlights[1].

On one side we pushed the quantum computing methods based on the Variational Quantum Eigensolver to a larger number of qubits (18 qubits). And on the other side, we have pushed the study of neural networks to matrix systems with matrices of larger and larger size.

3. Result

The results from the Variational Quantum Eigensolver with 18 qubits show that our published results are confirmed and that using a larger number of modes in the system produces values that are consistent with our previous extrapolations.
The results of the neural networks to approximate the wavefunction of a theory with large matrices are promising for the case of bosonic degrees of freedom and we plan to publish them in a forthcoming paper.

4. Conclusion

Deep learning paired with Variational Monte Carlo methods is a very promising avenue to study quantum many-body systems, from spin glasses to matrix models. Our project demonstrates the accuracy of this method on different quantum matrix models and also compares this method to recent quantum algorithms.

[1] Enrico Rinaldi, Xizhi Han, Mohammad Hassan, Yuan Feng, Franco Nori, Michael McGuigan, Masanori Hanada, "Matrix Model simulations using Quantum Computing, Deep Learning, and Lattice Monte Carlo", PRX Quantum 3, 010324, 2022

５. Schedule and prospect for the future

We expect to continue this project in the next fiscal year. We have obtained funding from the Royal Society in the UK to bring collaborators to RIKEN to continue this project in a promising new direction: we plan to study how to create wave functions of localized states in quantum matrix models as well as investigate their properties at finite temperature.

Usage Report for Fiscal Year 2022

Fiscal Year 2022 List of Publications Resulting from the Use of the supercomputer

[Paper accepted by a journal]

None

[Conference Proceedings]

None

[Oral presentation]

Enrico Rinaldi, "Quantum gravity in the lab: quantum computing and deep learning solutions", University of Tokyo, Komaba Campus, May 2022

Enrico Rinaldi, "Neural quantum states for supersymmetric quantum gauge theories", EPFL, Workshop on Variational Quantum Matter, Switzerland, July 2022

Enrico Rinaldi, "Neural quantum states for supersymmetric quantum gauge theories", Galileo Galilei Institute, Florence, School on machine learning methods in quantum physics, September 2022

Enrico Rinaldi, "Variational Quantum Algorithms for supersymmetric matrix models", MITP, Mainz, Germamy, Workshop on quantum methods for lattice gauge theories, November 2022

[Poster presentation]

None

[Others (Book, Press release, etc.)]

Enrico Rinaldi, Simon Pleasants, "**Quantum computing and deep learning could help solve the mysteries of quantum gravity**", RIKEN Research Highlights (web-link)