

CS 880: Quantum Algorithm

## Topic

We plan to do a project relating to Quantum Monte Carlo.

1. Mean Estimation [1–4]
2. Quantum Monte Carlo and Many-body Problem [5, 6]
3. Complexity of Negative Sign Problem (Quantum Monte Carlo) [7]
4. Interaction between Quantum Monte Carlo and Quantum Computing [8, 9]

## Planned Outline

We will firstly describe what is the classical Monte Carlo and what is quantum Monte Carlo. Then we will describe quantum algorithm for classical Monte Carlo (which is the one published in QIP 2023), and describe some quantum algorithm for quantum Monte Carlo.

We plan to follow the structure of lecture note from Yale [6] to learn and describe how Quantum Monte Carlo works.

We also tentatively plan to introduce the computational Complexity of a significant problem in Quantum Monte Carlo, the Negative Sign Problem, which is NP Hard [7].

We don't think we can actually tackle all of them, but the plan is to at least talk about the classical Monte Carlo and some introduction toward Quantum Monte Carlo.

## References

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- [2] Yassine Hamoudi. *Quantum algorithms for the Monte Carlo method*. PhD thesis, Université Paris Cité, 2021.
- [3] Ashley Montanaro. Quantum speedup of monte carlo methods. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 471(2181):20150301, 2015.
- [4] S. Heinrich. Quantum summation with an application to integration. *Journal of Complexity*, 18(1):1–50, 2002.
- [5] David Ceperley and Berni Alder. Quantum monte carlo. *Science*, 231(4738):555–560, 1986.
- [6] Boulder 2003 Summer School. *Computational Quantum Magnetism*. 2003.
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- [8] William J Huggins, Bryan A O’Gorman, Nicholas C Rubin, David R Reichman, Ryan Babbush, and Joonho Lee. Unbiasing fermionic quantum monte carlo with a quantum computer. *Nature*, 603(7901):416–420, 2022.
- [9] Yukun Zhang, Yifei Huang, Jinzhao Sun, Dingshun Lv, and Xiao Yuan. Quantum computing quantum monte carlo. *arXiv preprint arXiv:2206.10431*, 2022.