CHALLENGES IN NEURAL QUANTUM STATE PERFORMANCE: INSIGHTS FROM THE BOSE-HUBBARD MODEL WITH MAGNETIC FIELD

Eimantas Ledinauskas[1,2], Egidijus Anisimovas[1]

[1]Vilnius University
[2]Baltic Institute of Advanced Technology
eimantas.ledinauskas@ff.stud.vu.lt

In the field of ground state search and simulation of evolution for many-particle quantum systems, Neural Quantum States (NQS) are emerging as one of the leading methods [1]. Their expressive power and the diversity of possible architectures enable the efficient modeling of systems that are infeasible with other existing approaches [2]. However, NQS methods typically experience a significant drop in performance when applied to frustrated systems [3]. Currently, it remains unclear whether this issue can be completely addressed through modifications to the methods, or if it represents a fundamental limitation of NQS. In this work, we study the performance of NQS in the case of the Bose-Hubbard model under an external magnetic field. This model can exhibit frustration phenomena due to the presence of two length scales: one associated with the lattice period and the other with the magnetic length. We apply our previously developed method for ground state search [4] and systematically test various hypotheses regarding the reasons for the decrease in NQS accuracy with increasing magnetic field strength. Based on our findings, we propose and assess adjustments aimed at enhancing performance.

[1] Dawid, A., Arnold, J., Requena, B., Gresch, A., Płodzień, M., Donatella, K., ... Dauphin, A. (2022). Modern applications of machine learning in quantum sciences. arXiv preprint arXiv:2204.04198.

[2] Sharir, O., Shashua, A., Carleo, G. (2022). Neural tensor contractions and the expressive power of deep neural quantum states. Physical Review B, 106(20), 205136.

[3] Bukov, M., Schmitt, M., Dupont, M. (2021). Learning the ground state of a non-stoquastic quantum Hamiltonian in a rugged neural network landscape. SciPost Physics, 10(6), 147.

[4] Ledinauskas, E., Anisimovas, E. (2023). Scalable imaginary time evolution with neural network quantum states. SciPost Physics, 15(6), 229.