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Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Andrey Kardashin

PhD Program: Computational and Data Science and Engineering

Title of Thesis: On applications of variational quantum circuits

Supervisor: Professor Jacob Biamonte

Name of the Reviewer: Tim Byrnes

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Date: 15-04-2023**

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

Reviewers report should contain the following items:

- Brief evaluation of the thesis quality and overall structure of the dissertation.
- The relevance of the topic of dissertation work to its actual content
- The relevance of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications
- The summary of issues to be addressed before/during the thesis defense

This thesis examines variational quantum algorithms for various quantum tasks. After a brief introduction discussing quantum computing and tensor networks, the thesis goes onto discuss variational quantum computing where several physical methods are examined theoretically and experimentally. The main part of the thesis involves using tensor network states for variational quantum algorithms. This is a topic of recent interest and is a good contribution to the field. Finally, quantum machine learning for quantum channel discrimination and classification is examined. The thesis is very well written and it is of a high quality. The dissertation work and methods used are relevant to the actual content. The quality of the publications is good and there is a substantial number of them indicating consistency in the level of the research.

Some issues that may be considered:

-One aspect that may be nice to clarify is to discuss exactly in what way the hybrid quantum-classical variational tensor network approach constitutes a speedup over the classical case. There are a few aspects to this which could be discussed. First, naively, the speedup in the hybrid approach may be attributed to the exponential size of the Hilbert space in the quantum computer. However, estimating the expectation value of some observable is apparently faster but many measurements would need to be made to make the estimate, so how many measurements would be required? Then there is the aspect of the tensor network parameterization. Such classes of states were introduced originally as an efficient way to capture commonly occurring quantum states, e.g. ground states of Hamiltonians. The parameterization in terms of a fewer than exponential number of parameters can be leveraged to give a classical improvement, this is after all the reason of the success of methods such as matrix product states. So if there is a classical improvement in parameterizing such variational circuits, could we not use the variational tensor network states in a purely classical scenario and have the same speedup? Perhaps some discussion of this general point would be good to include as a motivation of the whole topic.

-In Eq. (2.12), the order parameter for the Schwinger model is given, citing Ref. [73]. I am not sure if this expression is actually in this paper. Ref. [73] did perform the first calculation of the Schwinger model using DMRG, which is equivalent to Matrix Product States and is related to the current work, however.

-In relation to the Schwinger model studied in Chapter 2, at least in the high energy physics/condensed matter physics sense, a two site system would not be considered to undergo a phase transition because the system is too small. The true phase transition only occurs in the limit of an infinite number of sites (thermodynamics limit).

Provisional Recommendation

☒ *I recommend that the candidate should defend the thesis by means of a formal thesis defense*
☐ *I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report*
☐ *The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense*