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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: Evgeniy Kiktenko

I confirm the absence of any conflict of interest	**Date:** 17-04-2023

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

The dissertation is structured into introduction, four chapters, conclusion and appendix. Overall, the thesis is fairly well-written, the logic is cohesive, and the structure is consistent.

The thesis studies the notion of variational quantum circuits, which is the core of variational quantum computing approach. The Introduction section outlines the topic of the dissertation, declares its goals, and lists the statements defended. Chapter 1 introduces the mathematical concepts used throughout the thesis: main definitions, basics of quantum computing, quantum circuits, and tensor networks notation. In Chapter 2, the author describes the variational model of quantum computing and gives the results related to the variational quantum eigensolver (VQE) algorithm. This is continued with Chapter 3, where several other existing variational quantum algorithms are reviewed and formulated in the tensor network notation. Chapter 4 considers the variational quantum computing approach for solving the problem of quantum channel discrimination. The Conclusion section discusses the content of the dissertation and states the results. In Appendix, the author gives a proof related to the cost function of a variational quantum algorithm, and also describes two subroutines used in quantum computing. The topic of the dissertation is therefore relevant to its content.

The results described in the dissertation are obtained mostly from numerical experiments. Where applicable, mathematical proofs are also given.

Chapter 2 contains the results on the numerical and experimental implementations of the VQE algorithm for Hamiltonians describing reliable physical models. Particularly, these results reveal the dependence of the performance of VQE on the properties of the ground state (e.g. entanglement) and noise present in the system. Chapter 3 reformulates some known variational quantum algorithms in the tensor networks notation, and also shows that they can be viewed as the VQE algorithm executed for specific Hamiltonians and variational states. Chapter 4 presents a practical approach for solving the problem of quantum channel discrimination on a quantum computer. The considered problems and obtained results are scientifically significant for certain.

The results related to the VQE could be of potential use in condensed matter physics. The results on quantum channel discrimination are of interest for the quantum machine learning community.

The results of the dissertation are reported in international peer-reviewed journals indexed in Scopus and Web of Science (Physical Review A and Frontiers in Physics).

Issues to be addressed:

1. In Section 4.1.3, when discriminating depolarizing channels with one channel application, why is the number of auxiliary qubits set to be two?
2. How the considered approach for variational quantum channel discriminates relates to discrimination of quantum channels by comparing corresponding Choi states (states obtained from maximally entangled bipartite state by acting with a channel of one part of this state)?

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*