

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Luis Ernesto Campos Espinoza

PhD Program: Computational and Data Science and Engineering

Title of Thesis: On the trainability of variational quantum circuits as algorithmic models

Supervisor: Professor Jacob Daniel Biamonte

Name of the Reviewer: Evgeniy Kiktenko

I confirm the absence of any conflict of interest	Date: 30-09-2024
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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 thesis by Luis Ernesto Campos Espinoza is dedicated to the topic of the quantum approximate optimization algorithm (QAOA), which is one of the most interesting and significant algorithms for noisy intermediate-scale quantum (NISQ) devices. The thesis is well-structured and clearly organized. The content is fully relevant to the topic under consideration. The main methods that combine analytical reasoning and numerical analysis are highly relevant to the study of the topic of the QAOA. The findings of the study make an important contribution to the field of quantum algorithms, as evidenced by the publication of three papers in the Physical Review A journal, which is ranked Q1 according to the SJR (<https://www.scimagojr.com>). The results can be applied within designing a training strategy for QAOA algorithms.

Below, I have provided a few suggestions that could improve the quality of the work.

1. I believe that one significant aspect that has been overlooked in the discussion of trainability limitations is the impact of finite-length statistical data used to estimate mean values of observables on the convergence of QAOA training in a real-world experimental setting. This factor, in my experience, has a significant effect on the success of QAOA optimization and should be addressed in the text in some way.
2. It would also be helpful to provide a description of the classical optimization algorithm employed in the various numerical experiments.
3. In Chapter 2, mean fidelity was used to measure the difference between the target k -Toffoli gate and the operation implemented by the ansatz under consideration. While this metric may seem reasonable at first glance, it demonstrates a somewhat counterintuitive behavior in that the distance between a true k -Toffoli gate and a "trivial identity" decreases as k increases. However, k -Toffolis and identities can be perfectly distinguished for any k by examining the output for an all-zero input. For this reason, other metrics such as the operator norm may be more appropriate for quantifying the actual distance between operations. It would be beneficial to gain some insight into how the conclusions regarding trainability transitions might change when using other target metrics.
4. The $|w\rangle\langle w|$ projector Hamiltonian considered in Chapter 4 is quite complex when written in terms of Pauli strings. Therefore, a brief discussion of the physical feasibility of (4.1) would be useful.

Minor technical comments

1. In order to ensure self-consistency, it is necessary to define N in the 5th "statement to defend".
2. Definition 8 appears to assume that all eigenvalues λ_j are distinct. If this is not the case, the definition should be modified slightly.
3. Time appears to have been omitted from the propagator following (1.20).
4. A definition of t^* within (1.26) is required.
5. An extra tab appears after (1.38).
6. Subscripts in Eq. (2.30) require a slight adjustment to the font.
7. The "otimesn" at the end of page 50 needs to be corrected.

Despite minor flaws, this is a thoroughly researched and well-organized work published in reputable academic journals. The results presented in the thesis are innovative and technically sound.

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~~