Skoltech
Skolkovo Institute of Science and Technology

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: Jingbo Wang

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Date: DD-MM-YYYY**

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

The variational model of quantum computing is pivotal in the noisy intermediate scale quantum (NISQ) era due to its perceived noise resilience; however, optimizing variational quantum circuits remains challenging. This thesis investigates various training strategies to improve their performance and explores limitations beyond the well-known barren plateaus (BP). Key findings include the identification of abrupt trainability transitions (ATT) in layerwise training, which require a critical number of layers for effective training, as well as the negative impact of identity initialization. Additionally, the research addresses training saturation (TS) in the quantum approximate optimization algorithm (QAOA), where training stops at certain depths; however, incorporating coherent phase noise can help mitigate this challenge. The thesis establishes an upper bound on circuit depth for achieving a close overlap with target states, suggesting methods to bypass conventional training processes. Overall, these results contribute to a better understanding of training limitations and enhance the viability of variational quantum algorithms in future developments beyond the NISQ framework.

In my opinion, this thesis has made significantly new contributions to scholarly knowledge in the subject area. It is a well-written, well-researched, and well-presented thesis on a contemporary subject in the field of quantum information. The literature review is comprehensive and in depth, and it is written in an authoritative, critical, and well-informed manner. The motivation for this work is explained clearly. The research reported in this thesis is important and innovative, and has been carried out with a sufficient degree of scientific rigour. Appropriate conclusions and discussions for future work are also included. The quality of the thesis meets internationally recognised standards for such work. I would therefore recommend that the thesis is passed and the degree is awarded after the candidate makes the below suggested changes.

- This thesis left a blank "Acknowledgments" page; it is important to acknowledge contributions and support that have influenced the candidate's academic journey and the development of the thesis.
- Please combine paragraphs which has only one or two sentences.
- Change to “layer-wise” throughout the thesis
- Page 28: add “.” to “in Figure 1-2.”
- Page 30: change to “This compilation problem dates back to the start of the field of quantum information processing [94]. It is encountered when implementing algorithms on quantum hardware, as the algorithm may require gates that are not part of the native gate set of the quantum computer [138, 139].”
- Page 37: change to “Then, we define abrupt trainability transitions, which affect variational quantum compilation when using a layer-wise strategy.”
- Page 49: change “the authors” to “we” or “the candidate and collaborators”
- Page 75: define “QAOA angles” when mentioned first time on this page
- Page 81: provide the correct reference and revise this sentence “… limiting effects fundamental to the variational model [?]ave been discovered.”
- Page 81: change to "Being by far the most studied limitation, barren plateaus (BP), as pointed out by [59], have come to be seen by many as equivalent to training limitations."
- Page 84: perhaps change to “We anticipate that as understanding of barren plateaus (BP) increases, there will be renewed interest from the community in other limitations, such as those discussed here. We believe that the insights gained from a broader exploration of training limitations will reinforce the variational model's position as a powerful and relevant approach beyond the NISQ era of quantum computing.”

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*