Skoltech
Skolkovo Institute of Science and Technology

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Akshay Vishwanathan

PhD Program: Computational and Data Science and Engineering

Title of Thesis: On quantum approximate optimization

Supervisor: Professor Jacob Biamonte

Name of the Reviewer: Dr. Zoltán Zimborás

I confirm the absence of any conflict of interest.	**Date: 10-04-2022**

Reviewer's Report

It is widely believed that combinatorial optimization could be one of the main application areas of near-term quantum computing. The Quantum Approximate Optimization Algorithm (QAOA) is a quantum optimization paradigm that is suitable for both analytical studies and practical implementations. For this reason this algorithm has become the most studied gate-based quantum optimization method. Akshay Vishwanathan's thesis on QAOA is thus a very timely work. The themes of the thesis is organized along three fundamental questions about QAOAs:
(1) What type of problems can a shallow depth (e.g., fixed constant depth) QAOA solve, and what are the fundamental limitations (reachability deficits) of QAOA?
(2) What type of features do optimal parameters have, e.g., is there a parameter concentration?
(3) Is there an empirical description of how many QAOA-levels we should choose to guarantee the performance of the QAOA?

The author reaches important results in connection to all the three questions. The essence of the results are summarized in the three main claims of the "statements defended" section. The overall structure of the thesis is also good. The first three chapters review the basic concepts: Chapter 1 introduces the notation and the used quantum computation concepts, Chapter 2 describes the formal theory of NP decision problems and establishes the equivalence between combinatorial optimization and Ising minimization, Chapter 3 introduces QAOAs. The next three chapters contain the results: in Chapter 4 the author identifies the fundamental limitations of QAOAs (the reachability deficits), in Chapter 5 an

analytical demonstration of the effect of concentrations of optimal circuit parameters is given, and in Chapter 6 author the proposes a predictive model about the the critical depth required for QAOA to guarantee an epsilon-tolerant performance. The concepts used are built up in a logical manner, and the presentation is clean. The methods used are state-of-the art and the proofs of the statements are convincing.

The quality of the thesis is excellent, and I firmly believe that results will have (and already had) a big impact on the field. The results are published in four first class articles of excellent quality. In particular, the paper on “Reachability deficits in quantum approximate optimization”, which has become a highly cited “classic” in the QAOA literature.

In summary, The thesis of Akshay Vishwanathan is well structured and contains many important results about the theory of Quantum Approximate Optimization Algorithms. It fulfills all demands required by a doctoral thesis. Thus, I can definitely recommend that the candidate should defend the thesis by means of a formal thesis defense.

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*