MASARYKOVA UNIVERZITA

Reviewer's report on Habilitation thesis

Reviewer: doc. RNDr. Jan Bouda, Ph.D.
Candidate: Ing. Martin Štefaňák, Ph.D.

Summary

The main subject of this thesis are quantum random walks. The chosen format is a collection of research papers together with an 87 page explanatory text. The collection contains 11 papers, which are a topic-selected subset of the whole publication record of the candidate.

I have to stress here that these are not even all candidate's papers on quantum random walks, it seems the selection was made even more strict to match the three areas (see below) specified in the explanatory part of the thesis, especially the ref. 65 of paper [I] would fit nicely, since it deals with two(multi)particle walks discussed in the thesis anyway.

The research topics discussed in the thesis are split into three areas, matched by three chapter of the explanatory text that I discuss separately.

Possible questions or topics the candidate should address during the defense are typeset in *italics*.

Analytical methods for Homogenous Coined Quantum Walks

This chapter puts emphasize on the development of mathematical techniques achieved by the candidate, and demonstrates their usefulness via various application on quantum walks. The key contribution here is to select a suitable basis for the coin space, what significantly reduces the complexity of the Fourier analysis, and allows calculations that otherwise would not be possible. The usefulness of this technique is well justified by the scientific results.

I would like to make a side comment, since candidate's papers referenced in this chapter and used here primarily as a demonstration of mathematical techniques, contain also results of practical interest. The two(multi) particle walk seems to be a very interesting concept.

Why did you concentrate on the "directional correlations" (I skip here the exact definition of the term)? I would be more curious about the general joint distribution and correlation between particle positions, namely the results outlined in sec. 6 of ref. [I]. Did you subsequently generalize these results?

Trapping Effect in Quantum Walks

The central topic here is the trapping effect, a specific situation occurring in certain types of quantum walks (e.g. three direction walk on a line with Grover coin). Trapping effect as described here is a non/vanishing probability of the starting point of a random walk.

Candidate performs an in-depth analysis of the problem, first (chronologically) linking this effect to the existence of the point spectrum in the Fourier transformation of the evolution operator. In subsequent papers candidate classifies extensively quantum walks that exhibit the trapping effect.

The trapping effect is clearly an interesting effect, although rather undesirable for most applications, and, hence, the primary impact of such studies should be not to design a random walk with a trapping effect. While the trapping effect seems to be rather rare (zero-measure), it nevertheless occurs in some standard techniques, namely with the Grover coin.

I would like to ask whether the candidate knows about any positive effect, i.e. about any application of a random walk, where the trapping effect is desirable?

Can you explain in more detail the role of the parameter \varphi on page 55 on the speed of the spread of walks through the lattice? Unlike the trapping effect, the spreading speed is a straightforward desirable effect in many applications.

Quantum Walk Approach to Perfect State Transfer

The central topic here is the implementation of the so called state transfer by quantum walks. Candidate modified a graph variant of the Grover search to implement the state transfer for a particular graphs (namely star graph and complete graph with loops).

I have to admit the state transfer problem seems a bit esoteric to me. Originally it seemed to be a cute idea that can be used to circumvent particular implementation problems that may arise when creating quantum circuits on some architectures. On the other hand, I have my doubts whether it really may be a more practical approach to implementation of quantum computation.

Considering this, the idea to implement the state transfer by quantum walks seem even less reasonable to me. It means using a very strong and not easy to experimentally implement technique to implement something with (from my point of view) doubtful usefulness.

Are there any other applications of state transfer, beyond the original motivation to be used as a part of the quantum computer hardware enabling interactions between distant qubits? Do they justify the usage of quantum walks?

Conclusion

Candidate presented a collection of research papers and demonstrated ability to

i) Find scientifically interesting and challenging areas of research and problems that lead to a sequence of research papers.

ii) Solve these problems using a non-trivial mathematical apparatus, while making a contributions to this apparatus that are of an interest that goes beyond the particular problems analyzed by the candidate.

I'm happy to recommend to accept this thesis.

In Brno on April 17th 2018

Jan Bouda

doc. RNDr. Jan Bouda, PhD.
Faculty of Informatics, Masaryk University
Botanická 68a, 602 00, Brno, Czech Republic