Topological invariants of quantum walks

Jan Wójcik[1]
Andrzej Grudka[2], Marcin Karczewski[3],
Paweł Kurzyński[2], Antoni Wójcik[2]

[1] *Faculty of Physics, Adam Mickiewicz University, 61-614 Poznań, Poland*
[2] *Institute of Spintronics and Quantum Information, Faculty of Physics,*
Adam Mickiewicz University, 61-614 Poznań, Poland
[3] *International Centre for Theory of Quantum Technologies, University of Gdańsk, 80-309 Gdańsk, Poland*
janwoj2@st.amu.edu.pl

We focus our presentation on discrete-time quantum walks and their topological properties. Quantum walks are periodically driven (Floquet) systems. Their discrete model due to its simplicity may be a very powerful tool while studying complex systems. They've been studied both theoretically and experimentally [1]. As was previously shown even the most basic model of the quantum walk may have some interesting topological properties. Quantum walks can help study topological phenomena as was shown in [2-3]

The dynamic of a quantum walk consists of two parts, the step of the walker and the coin toss. We can distinguish the topological properties of the quantum walk based on the coin toss operator.

We define topological properties for translational invariant walks. Due to this symmetry, we define a unique map from the first Brillouin zone to the Bloch sphere. We want to infer the topological properties of discrete-time quantum walks only by studying this map.

Until now the most popular way to approach the distinction of topological phases in quantum walks is the usage of a winding number.

In a recent paper [5] we show possible issues regarding inferring the topological properties of a quantum walk only from studying the winding number. We propose a new approach. Using relative homotopy we propose a new topological invariant. We show that it agrees with previous models and more generalized ones. Our invariant indicates the number of edge states at the interface between two topological phases. We identify those states for arbitrary coin toss operators. Those states we found to be protected by PHS. We managed to find the exact form of topological edge states in the sharp edge model.

References

[1] J. Wu, W.-W. Zhang, and B. C. Sanders, Frontiers of Physics 14, 61301 (2019).
[2] F. Harper, R. Roy, M. S. Rudner, and S. L. Sondhi, Annual Review of Condensed Matter Physics 11, 345 (2020).
[3] T. Kitagawa, Quantum Information Processing 11, 1107 (2012).
[4] T. Kitagawa, M. S. Rudner, E. Berg, and E. Demler, Physical Review A 82, 033429 (2010).
[5] A. Grudka, M. Karczewski, P. Kurzyński, J. Wójcik and A. Wójcik, Phys. Rev. A 107 (2023) 032201.

Figures

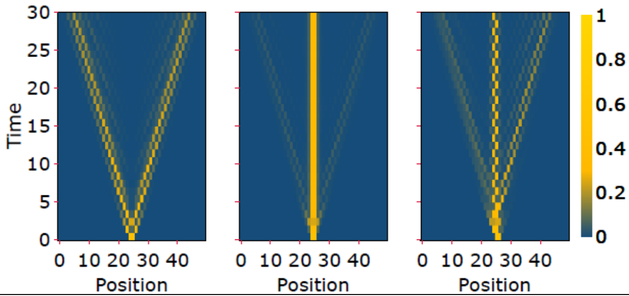

Figure 1: Simulation of basic quantum walk with two distinct topological phases. The color of the legend imposes the probability of finding the walker in position "x" and time "t". Simulations differ because of the initial state of the walker. On the left, the state of the walker is orthogonal to both edge states, in the middle one, the state has non-zero overlap with only one of the edge states whereas the right one has non-zero overlap with both edge states.