Quantum State Diffusion on a Graph

John C Vining III*, Howard A. Blair, Syracuse University

Quantum walks have traditionally envisioned the behavior of a quantum state traversing a classically defined, generally finite, graph structure. While this approach has already generated significant results, it imposes a strong assumption: all nodes where the walker is not positioned are quiescent. This paper will examine some mathematical structures that underlie state diffusion on arbitrary graphs. We will seek to frame the multi-walker problem as a finite quantum cellular automaton. Every vertex holds a walker at all times. The walkers will never collide and at each time step their positions update nondeterministically by a quantum swap of walkers at opposite ends of a randomly chosen edge. The update is accomplished by a unitary transformation of the position of a walker to a superposition of all such possible swaps and then performing a quantum measurement on the superposition of possible swaps. This behavior provides a path toward developing local actions which produce diffusion throughout the graph without depending on the specific structure of the graph.

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