Quantum Physics

Framework for discrete-time quantum walks and a symmetric walk on a binary tree

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We formulate a framework for discrete-time quantum walks, motivated by classical random walks with memory. We present a specific representation of the classical walk with memory 2 on which this is based. The framework has no need for coin spaces, it imposes no constraints on the evolution operator other than unitarity, and is unifying of other approaches. As an example we construct a symmetric discrete-time quantum walk on the semi-infinite binary tree. The generating function of the amplitude at the root is computed in closed-form, as a function of time and the initial level n in the tree, and we find the asymptotic and a full numerical solution for the amplitude. It exhibits a sharp interference peak and a power law tail, as opposed to the exponentially decaying tail of a broadly peaked distribution of the classical symmetric random walk on a binary tree. The probability peak is orders of magnitude larger than it is for the classical walk (already at small n). The quantum walk shows a polynomial algorithmic speedup in n over the classical walk, which we conjecture to be of the order 2/3, based on strong trends in data.

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