Quantum Physics

Asymptotic entanglement in a two-dimensional quantum walk

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The evolution operator of a discrete-time quantum walk involves a conditional shift in position space which entangles the coin and position degrees of freedom of the walker. After several steps, the coin-position entanglement (CPE) converges to a well defined value which depends on the initial state. In this work we provide an analytical method which allows for the exact calculation of the asymptotic reduced density operator and the corresponding CPE for a discrete-time quantum walk on a two-dimensional lattice. We use the von Neumann entropy of the reduced density operator as an entanglement measure. The method is applied to the case of a Hadamard walk for which the dependence of the resulting CPE on initial conditions is obtained. Initial states leading to maximum or minimum CPE are identified and the relation between the coin or position entanglement present in the initial state of the walker and the final level of CPE is discussed. The CPE obtained from separable initial states satisfies an additivity property in terms of CPE of the corresponding one-dimensional cases. Non-local initial conditions are also considered and we find that the extreme case of an initial uniform position distribution leads to the largest CPE variation.

Comments:	Major revision. Improved structure. Theoretical results are now separated from specific examples. Most figures have been replaced by new versions. The paper is now significantly reduced in size: 11 pages, 7 figures
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