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Continuous-time quantum walks in the presence of a quadratic perturbation

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We address the properties of continuous-time quantum walks with Hamiltonians of the form $H = L + \lambda L^2$, being L the Laplacian matrix of the underlying graph and being the perturbation λL^2 motivated by its potential use to introduce next-nearest-neighbor hopping. We consider cycle, complete, and star graphs because paradigmatic models with low/high connectivity and/or symmetry. First, we investigate the dynamics of an initially localized walker. Then, we devote attention to estimating the perturbation parameter λ using only a snapshot of the walker dynamics. Our analysis shows that a walker on a cycle graph is spreading ballistically independently of the perturbation, whereas on complete and star graphs one observes perturbation-dependent revivals and strong localization phenomena. Concerning the estimation of the perturbation, we determine the walker preparations and the simple graphs that maximize the Quantum Fisher Information. We also assess the performance of position measurement, which turns out to be optimal, or nearly optimal, in several situations of interest. Besides fundamental interest, our study may find applications in designing enhanced algorithms on graphs.

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