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Computing n-time correlation functions without ancilla qubits

The n-time correlation function is pivotal for establishing connections between theoretical predictions and experimental observations of a quantum system. Conventional methods for computing n-time correlation functions on quantum computers, such as the Hadamard test, generally require an ancilla qubit that controls the entire system – an approach that poses challenges for digital quantum devices with limited qubit connectivity, as well as for analog quantum platforms lacking controlled operations. Here, we introduce a method to compute n-time correlation functions using only unitary evolutions on the system of interest, thereby eliminating the need for ancillas and the control operations. This approach substantially relaxes hardware connectivity requirements for digital processors and enables more practical measurements of n-time correlation functions on analog platforms. We demonstrate our protocol on IBM quantum hardware up to 12 qubits to measure the single-particle spectrum of the Schwinger model and the out-of-time-order correlator in the transverse-field Ising model. In the demonstration, we further introduce an error mitigation procedure based on signal processing that integrates signal filtering and correlation analysis, and successfully reproduces the noiseless simulation results from the noisy hardware. Our work highlights a route to exploring complex quantum many-body correlation functions in practice, even in the presence of realistic hardware limitations and noise.

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