Efficiently Tracking Quantum Entanglement: The Machine Learning Edge in Non-Markovian Open Dissipative Systems

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Quantum open systems account for unavoidable interactions with environmental noise such as energy dissipation crucial for modeling realistic quantum dynamics. Additionally, colored noise in Non-Markovian dissipative systems is of interest due to its role in preserving quantum coherence and entanglement through memory effects. However, there is a major challenge for retrieving quantum information with both experimental measurements and numerical simulations: the complexity of a system's state scales quickly with the number of qubits and the evolution's time span. Additionally, the former method requires extensive experiments due to numerous observables and the probabilistic nature of quantum mechanics, whereas the latter is often infeasible due to unobtainable information about the initial state or system parameters. We look for a more efficient approach to overcome these difficulties and successfully track the evolution of quantum entanglement in an open Non-Markovian environment. To create the training dataset, we simulate the dynamics of a two-qubit system using a modified form of the Lindblad master equation. Then, we use a multilayer perceptron (MLP) model to piece together the full time evolution from sparse quantum state data without requiring known initial conditions. Additionally, we use convolutional neural networks (CNN) to extrapolate unobservable parameters and initial conditions from quantum state data. Our findings can speed up realistic quantum processes, such as quantum sensing, quantum state reconstruction, and fast quantum information retrieval in general. One key feature of our approach is that high-fidelity information retrieval is possible even when the system parameter information and initial states are not available.

Awards Won: