Efficient Computation of Interference Between Pathways in Quantum Control Systems

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Quantum control is the technique of using an external influence, such as a shaped laser pulse or an oscillating magnetic field, to manipulate the dynamics of a quantum system. Hamiltonian encoding is a previously-developed method for revealing the mechanism behind the dynamics governing quantum control systems. In this context, mechanism is defined by pathways that describe the evolution of the system from its initial state to its final state through one possible sequence of intermediary states. Each pathway is associated with a complex pathway amplitude corresponding to a term in the Dyson series. The interactions between pathway amplitudes describe the way different pathways constructively and destructively interfere to determine the evolution of the system. Sets of pathways with similar attributes can be grouped together into pathway classes whose associated amplitude is the sum of the amplitudes of its constituent pathways. These pathway class amplitudes are calculated by encoding the Hamiltonian and decoding the subsequent evolution of the system instead of by direct computation. In its current form, Hamiltonian encoding is highly computationally intensive, making it difficult to apply to large quantum systems. This work presents new ways to calculate the amplitudes of pathway classes by exploiting topological patterns in the set of the allowed transitions to limit the number of transitions that need to be encoded. These improvements lead to an exponential decrease in both computation time and memory usage, which in practice often corresponds to roughly a millionfold improvement. These techniques are applied to multi-qubit nuclear magnetic resonance systems to demonstrate their promising applications in quantum computing research.

Awards Won:

Shanghai Association for the Advancement of Science for Youths: Science Seed Award