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Quantum Complexity and efficient synthesis of quantum evolution in the presence of noise

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The presence of an environment perturbing a quantum system introduces errors that can hinder information storage and processing in quantum computers. Minimizing these errors requires efficient synthesis of the desired evolution. A key concept in achieving this goal is quantum complexity, which measures the difficulty of synthesizing a specific evolution. (1) Traditionally, quantum complexity is quantified by the number of gates from a universal gate set needed to generate a desired unitary transformation. In our approach, we used the redefined complexity: it is the length of the geodesic connecting the system identity to the desired unitary evolution. (2) Previous studies have explored the use of recurrent neural network architectures for predicting control sequences to synthesize desired unitaries. (3) Our research builds upon these references by introducing noise to the steered Hamiltonian. We model noise as a non-controllable drift Hamiltonian and purify the system by adding one ancillary qubit for the qubit of interest. The drift Hamiltonian is modeled by a dephasing noise, based on the Caldeira-Leggett theory of Brownian motion. By using artificial neural networks that predict good costates of the desired evolution, and using usual minimization tools on the predicted costates, we are able to obtain infidelities of 10^{-8} between predicted and target unitaries. Furthermore, we investigate the impact of noise on complexity. Specifically, we explore how the inclusion of noise affects the number of gates required for synthesis. By advancing the understanding of efficient synthesis techniques and accounting for noise effects, our research contributes to improving the reliability and performance of quantum computing systems.

Palavras-chave: Computação quântica. Teoria de controle. Aprendizado de máquina.

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