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Noisy Gates for Quantum Computing

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Assessing the effect of noises in quantum computers is a major task for understanding their practical applicability for solving real-life problems. In quantum mechanics, and in particular in quantum computation, noises emerging from the interaction of a system with its surrounding environment is formulated in terms of the density matrix. The theory is well developed, but from the computational point of view resorting to the density matrix instead of the state vector makes the problem quadratically more difficult to solve.
We propose a scheme called Noisy Gates, that uses state vectors evolving according to a stochastic Schrödinger equation. This description is statistically equivalent to the density matrix formulation: by taking the average over different noise realizations, one recovers the evolution of the density matrix. At the same time, it presents the computational advantage of working with the state vector.
Moreover, differently from the standard approach in which the gate and noise are decoupled, the solution of stochastic Schrödinger equations is a linear and stochastic matrix, mathematically equivalent to a quantum gate that mixes the effects of the noise with the unitary action of the gate. This provides a more accurate physical description and it gives our method its name, Noisy gates. By finding the expressions for these noisy gates, one can perform classical simulations of noisy quantum algorithms on quantum computers, in order to analyze error propagation and devise strategies to mitigate them.

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