Automated Quantum Error Correction Protocols without Measurement

Pradip Bhattarai* and Sangchul Oh†
Department of Physics, Southern Illinois University, Carbondale, Illinois, 62901, United States

Kishor T Kapale‡
Department of Physics, Western Illinois University, Macomb, Illinois, 61455, United States

Quantum error correction (QEC) is vital for protecting quantum information from noise and decoherence. Traditional QEC encodes a logical qubit into physical qubits, detects errors using ancilla qubits, and corrects errors based on the measurement outcomes of the ancilla qubits. However, current quantum computers lack sufficient qubits for full QEC, and measurements are both time-consuming and prone to errors. These limitations hinder the fast and effective implementation of QEC codes on today's noisy quantum devices. Here, we propose a novel measurement-free error-correction protocol by employing multi-qubit gates controlled by ancilla states. The proposed protocol was tested on IBM's Qiskit platform, both through simulations and real quantum hardware implementations. The circuits, including 3-, 7-, and 9-qubit codes, demonstrated effective error correction in simulations but were less effective on current hardware, highlighting the challenges of noisy intermediate-scale quantum (NISQ) devices. Looking forward, this measurement-free approach offers significant promise for quantum error correction in future quantum systems. As hardware improves, automated error correction protocols may enable more efficient and scalable, playing a crucial role in fault-tolerant quantum computation.

KEYWORDS

Quantum Computing, Fault-Tolerance, Error Correction

* Pradip.bhattarai@siu.edu
† sangchul.oh@siu.edu
‡ kt-kapale@wiu.edu