Dynamical Decoupling Error Mitigation on Quantum Applications

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Today's quantum computers are prone to errors in the Noisy Intermediate-Scale Quantum (NISQ) era. Since there are not enough resources to realize quantum error correction, an alternative approach for quantum error mitigation was proposed, aiming at reducing the impact of errors to explore useful NISQ applications.

Dynamical decoupling (DD) is one of the simplest methods to suppress decoherence error without additional circuit overhead. The thrust of DD is to insert periodically a series of pulses to the idle qubits and return the qubits to their original states. Various DD strategies have been proposed, including non-universal, universal, and robust ones with different impacts. However, it has been demonstrated that the naive implementation of some of the DD techniques (inserting DD sequences to all the idle qubits) cannot always be beneficial to the circuits [1]. The state-of-the-art application-level DD insertion methods require a large overhead of tuning DD pulses by executing several additional circuits [1-2].

In our work [3], we address the following questions: (1) What are the impacts of different sequences on specific applications? (2) For a certain benchmark, does the impact of different DD sequences vary across different quantum chips. We study all the popular DD strategies, such as CPMG, XY4, UDD, KDD, and explore their performance in various quantum applications, including Bernstein-Vazirani (BV) algorithm, Hidden Shift (HS) algorithm, Quantum Fourier Transform (QFT), Graph State (GS), and QAOA. We evaluate the experiments on several IBM devices with different qubit numbers and quantum volumes.

We define application-specific metrics to evaluate the difference of each application before and after inserting DD sequences. Some of the results are shown in Figure 1. For the complete results, please refer to our paper [3]. Based on the experimental results, we found that DD techniques always show a positive impact on some benchmarks, such as BV and QAOA. Whereas for others, DD demonstrates some discouraging effects. We also provide a list of design guidelines for users to better understand different DD techniques and figure out how to improve the circuit design for various quantum applications.

References

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[2] G. S. Ravi, K. N. Smith, P. Gokhale, A. Mari, N. Earnest, A. Javadi-Abhari, and F. T. Chong, Vaqem: A variational approach to quantum error mitigation, arXiv:2112.05821, 2021.

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Figures

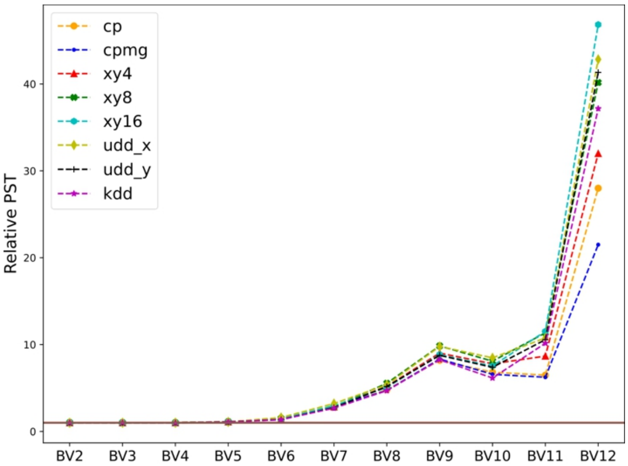

Figure 1: Relative PST results for BV circuits on IBM Q 27 Montreal. Higher is better.