QEC Model Zoo Abstract

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Nowadays, quantum computers have high error rates, where qubits are easily disturbed by noise. Quantum error correction (QEC) plays an important role in fault-tolerant quantum computing. It encodes the fragile physical qubits into reliable logical qubits, continuously detecting and suppressing errors. In this work, we focus on QEC decoding. Conventional QEC decoders, such as minimum-weight perfect matching [1] and Chromobius [2], are well established and widely used across different QEC code families, but they share some common limitations, for instance: 1) their computational cost grows quickly with code distances; 2) they are sensitive to noise in real quantum hardware; and 3) they have to meet strict latency requirements. Machine learning offers a complementary alternative for QEC decoding, because it can learn decoding rules directly from data, instead of fully relying on analytical noise models. In recent years, AI-enhanced decoders are increasingly explored across QEC code families. Nevertheless, reported gains in existing works are difficult to interpret since they differ in datasets, input representations, preprocessing, models, and evaluation protocols.

To bridge this gap, we present *QEC model zoo* [3], a data-centric benchmark spanning nine real quantum experimental datasets and four circuit-level QEC data simulations, covering repetition, surface, color, and bivariate bicycle codes and parity checks. We define separate benchmark tasks for AI-based full decoders on real QEC datasets, which predict logical errors directly, and learned pre-decoders and transformer-based neural decoders on simulated QEC codes. The model zoo provides task-specific protocols that standardize input representations, preprocessing, training pipelines, and evaluation metrics for reproducible comparison. Our results demonstrate that decoder choice depends on both the dataset and the available computation time. Input representation substantially affects tabular decoder performance. The results also show that TabM and tree ensembles are the most accurate on eight of nine datasets. These findings reveal how input representation, inference-time constraints, and pipeline integration affect decoder performance.

References

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