Neural network decoding of quantum error correction experiments using soft measurement information

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In recent years, there has been interest in small-scale quantum error correction experiments such as scaling a surface code from distance d=3 to d=5 for superconducting qubits [1]. Neural network decoders can offer an alternative to conventional decoders, such as minimum-weight-perfect-matching (MWPM) and variants, and can provide an advantage when dealing with non-conventional errors, such as leakage and crosstalk. Until recently, neural network decoders have only been applied to simulated data with Pauli errors. In our work, we apply a recurrent neural network to decode experimental data from several superconducting experiments. For experiments on d=3 and d=5 surface codes, with a decoder trained on simulated data but applied to experimental data, we show performance close to a Belief-Matching decoder, see Figure 1. We also show a decoding advantage in using soft measurement data [4]. For experimental data of a Surface-13 (only correcting bit-flip errors) experiment, we train and apply the neural network decoder with experimentally available soft measurement information and outperform MPWM with either soft or hard information, see Figure 2. We also show that the neural network decoder can use leakage information to improve its performance. Finally, we discuss how this method of decoding can be used for decoding logical gates and larger distance codes.

This talk is based on the work carried out in Ref. [2] and Ref. [3].

References

[1] Google Quantum AI. Nature 614 (2023) 676-681
[2] Boris M. Varbanov et al., arXiv (2023) 2307.03280
[3] Hany Ali et al., (in preparation)
[4] Christopher A. Pattison et al., arXiv (2021) 2107.13589

Figures

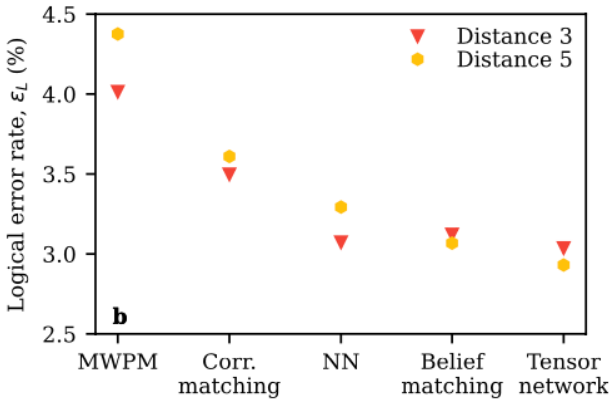

Figure 1: Logical error rate for different decoders, including the neural network, evaluated on experimental data from d=3 and d=5 surface codes [2]

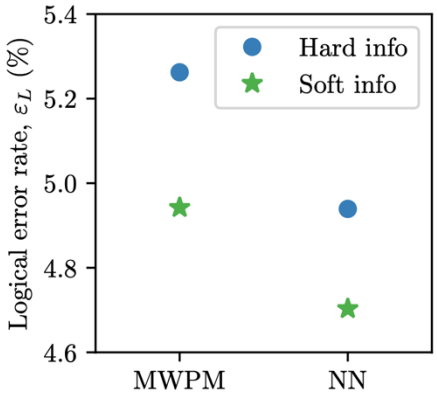

Figure 2: Logical error rate for the neural network and MWPM decoders evaluated on experimental data using soft and hard measurement information from a Surface-13 code [3]