Neural Network Decoder for Heavy-Hexagon Quantum Error Correction Code

Background & Motivation

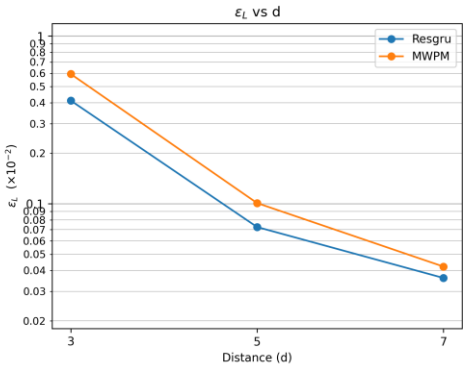
QPA Research Group

- Quantum Error Correction (QEC) is essential key for Fault-tolerant Quantum Computation
- Accuracy and efficiency of QEC depends on accuracy and latency of decoder used to decode the syndrome data generated by QEC code
- Existing graph based decoders struggle with the complex noise and fails to maintain the required throughput
- Several neural network based techniques have been developed to decode the QEC codes but they struggle with scaling
- Heavy-hexagon is the qubit topology of IBM quantum computers which are most widely available, however there still very limited research in neural network decoder for heavy-hexagon (HH) quantum error correction code.

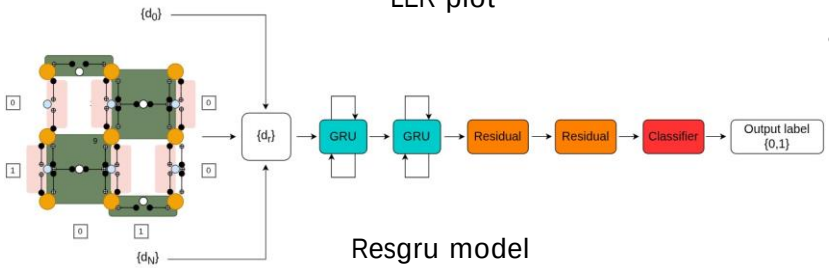
Kumar, A., Haghparast, M., & Kettunen, L. (2026). Resgru: Syndrome decoder for heavy-hexagon quantum error correction code. *Physica Scripta*.

http://doi.org/10.1088/1402-4896/ae87e2

Proposed Research Item and Goal



LER plot



Resgru model

- We developed a neural network decoder for heavy-hexagon quantum error correction code which uses combination of Gated Recurrent Unit (GRU) and Residual layer hence called Resgru.
- The recurrent model can map temporal correlation in syndrome data which increases the accuracy of our model. Also, use of GRU reduces the number of parameters hence making it scalable.
- We benchmarked our model against standard MWPM decoder under circuit level depolarizing noise model for distance 3,5 and 7 HH code. Our model gave 30%, 28% and 14% reduction in logical error rate (LER) at distance 3,5 and 7 respectively.

▶ Status: Paper has been submitted for publication and is under review ◀