The Recursive MWPM decoder

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Quantum computers promise ground breaking effects in several research fields such as cryptography or pharmacology. Thus, a large community of scientists continuously develop new and better optimized quantum algorithms which will hopefully contribute to the advancements a future quantum computer will yield. Nevertheless, for a quantum computer to be reliable in its computations, it must be fault-tolerant. That is, it needs to be able to endure quantum decoherence within its qubits without having its operations compromised. The field of study of fault-tolerance within quantum computing is known as Quantum Error Correction (QEC). A common approach within QEC in order to protect the qubits consists in storing their information within a larger set of qubits named Quantum Error Correction Codes (QECCs). The process of recovering an error which is expected to have been the one which interacted with the code is named decoding. The most popular QECC at the moment is the surface code. Surface codes consist in displaying the qubits which encode the information of the code in the vertices of a 2D-lattice, while other qubits which are used for obtaining syndromes are also displayed corresponding a 2D-lattice structure. Moreover, surface codes are the only type of QECC to be experimentally tested [1,2]. The surface codes can be decoded through various decoding schemes, nevertheless the most popular is named the Minimum Weight Perfect Matching decoder (MWPM). The MWPM method excels in performance for surface codes, but it can struggle when considering realistic quantum channels, such as the biased channel or the independent non-identically distributed (i.ni.d.) error model. For this poster, we cover a variation of the MWPM decoder which significantly improves the performance of the conventional MWPM by considering correlations between errors, the recursive MWPM (recMWPM). Normally, the conventional MWPM decodes a syndrome by considering X and Z-errors independently. Nevertheless, doing so omits the impact of Y-errors, which for mathematical reasons can be considered products of X and Z, and the probability rate of which is considered to be similar to the X-error one. The recMWPM uses the computation of MWPM in one of the two subgraphs to reweight the edges from the other in a recursive manner until both subgraphs agree in the same result. This variation on the decoding consideration significantly enhances the performance of the decoder (as can be seen in Figure 1) at the expense of a complexity parameter, which can be adjusted at will.

References

[1] Sebastian Krinner et al., Nature, 605, (2022) 669-674
[2] Google Quantum AI, Nature, 614 (2023) 676-681

Figures

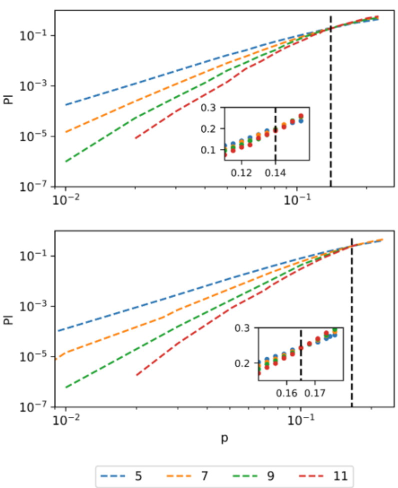

Figure 1: Logical error with dependence on the physical error probability for rotated planar codes under depolarizing noise being the conventional MWPM (top) and by the recMWPM (bottom).