The closed-branch decoder for quantum LDPC codes

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Quantum computers promise an advantage over classical computers for certain tasks, which may provide groundbreaking computation capabilities of use for several research fields. Unfortunately, quantum decoherence prevents us from reaching their full potential. Qubits, which are the most fundamental constituents of quantum processors, tend to interact in non-trivial ways that we cannot predict nor control, thus there is a pressing necessity for correcting the non-desired errors qubits may experience because of their interaction with the environment. The field within quantum computing which aims to tackle this unfortunate phenomenon is named quantum error correction [1]. Quantum error correcting codes consist in protecting the information of a number of clean (logical) qubits by means a much larger set of noisy qubits, referred as physical qubits. If a number of the constituent qubits undergoes a non-trivial Pauli error, we receive partial information of it through a vector commonly named as syndrome. The algorithm that receives a syndrome as input and returns an estimate of the error is named the decoder, and it is of pivotal importance in quantum error correction [1,2].

The decoder of choice for general quantum error correcting codes (QLDPC) is the belief propagation order statistics decoder (BPOSD) [3], an algorithm with good accuracy but too slow. Real-time decoding in superconducting quantum processors would require decoding algorithms to be executed in an order of microseconds. Achieving a decoder that is fast at enough accuracy is necessary if we want to reach quantum fault-tolerance.

Given the introduced context, we propose a new decoder named the closed-branch decoder [4] which scales as O(n*m), where n is the number of qubits within the code and m is a tuneable parameter. Its accuracy is good enough requiring much less complexity than BPOSD. In the presentation, I will cover the structure and intricacies of this new decoder.

References

[1] Stabilizer Codes and Quantum Error Correction, Gottesman, PhD manuscript, (1997).

[2] Decoding algorithms for surface codes, deMarti iOlius, Fuentes, Orús, Crespo & Etxezarreta Martinez, arXiv preprint (2023).

[3] Degenerate quantum LDPC codes with good finite length performance, Panteleev & Kalachev, Quantum, 2521-327X (2021).

[4] The closed-branch decoder for quantum LDPC codes, deMarti iOlius & Etxezarreta Martinez, arXiv preprint (2024).

Figures

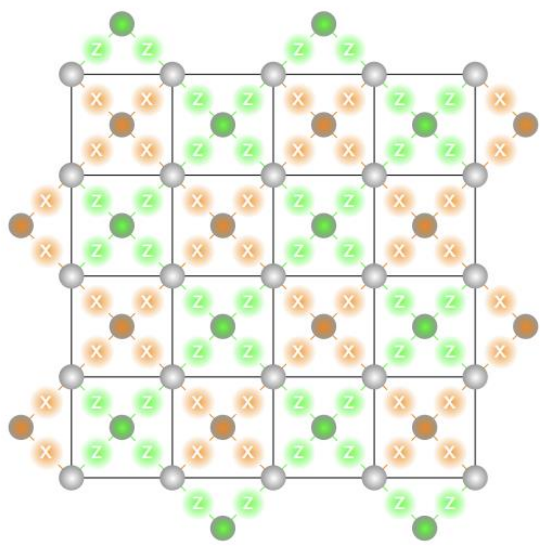

Figure 1: Surface code, a type of quantum error correcting code.