Karlsruher Institut für Technologie

Communications Engineering Lab (CEL)
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Decoding of Quantum LDPC Codes with Modified Belief Propagation Decoder

Master's Thesis

Project

Quantum error-correction codes (QECCs) are essential components in quantum computers (QCs), designed to protect the fragile quantum states from unwanted evolution and to allow robust implementations of quantum processing devices. The near-capacity performance of classical low-density parity-check (LDPC) codes and their efficient iterative decoding makes quantum LDPC (QLPDC) codes a promising candidate for quantum error correction. In the past few years, various QLDPC families have been proposed which yield significant performance improvement.

However, belief propagation (BP) decoder cannot be applied to QLDPC codes due to the so-called degeneracy phenomenon of quantum codes, a specific property with no classical counterpart. Several successful modifications of the BP decoder have been proposed. Among them, the combination of BP and ordered statistics decoding (OSD) yields surprisingly good performance. Moreover, there is no general decoding algorithm that decodes all QLDPC codes efficiently so far. Thus, designing QLDPC codes comes with the price of developing a special-purpose decoding strategy. Since there has been evidence suggesting that BP-OSD decoding works as a general-purpose decoder for the family of hypergraph product QLDPC codes, it is interesting to find out if such BP-OSD decoding applies to more general types of QLDPC codes.

In this thesis, modified BP decoders for QLDPC codes should be implemented and the performance should be evaluated upon different families of QLDPC codes. Ideally, an optimization of the decoding strategy should be proposed and evaluated as well.

Deliverables

1. Become acquainted with quantum error correction, in particular, QLDPC codes and their decoders.
2. Implementation and performance evaluation of belief propagation with different modifications for QLDPC codes.
3. Investigation and development of novel BP strategies and modifications for code-agnostic decoding.

Requirements

- ✓ Interest in quantum information theory and error correction
- ✓ Good skills in at least one programming language (e.g. C/C++)
- ✓ Good knowledge of linear algebra, channel coding, classical LDPC codes and belief propagation decoding (CC2, CCAM)

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