Decoding of Topological Quantum Codes

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Quantum information needs to be protected by quantum error-correcting codes due to imperfect quantum devices and operations. One would like to have an efficient decoding procedure for practical quantum codes, such as toric and surface codes. Currently the state-of-the-art minimum-weight perfect matching decoder has complexity polynomial in the code distance; a decoder of complexity linear in the code distance is desired. A potential candidate is Pearl's belief propagation (BP), but its performance suffers from the many short cycles inherent in quantum codes. We show that BP can exploit the degeneracy of quantum codes and have significantly improved performance. In particular, we achieve a high decoding threshold (14~16%) for the surface codes in the ideal circuit model.