Quantum Error Correction

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Quantum computers in theory, are predicted to outperform classical computers in certain tasks. Quantum computers in practice however, are fragile, having to contend with sources of noise and decoherence both in a quantum memory persisting over time and in the implementation of computational gates. Quantum error correction is the study of solutions to this problem based on the encoding of logical information into larger more protected physical systems. The design of such codes is an active area of research and an inherently interdisciplinary topic, at the intersection of physics, computer science, and mathematics. In this course we will learn the necessary pre-requisites to design, analyze, and use quantum error correcting codes. We will particularly focus on the toric / surface code due to its simplicity, its performance, and its relevance to current research. It will serve as a tool to introduce more advanced concepts.

Organization This lecture is structured into 8 time slots, each lasting 3 hours. 6 time slots of lecture + tutorials, mixed. The last 2 time slots will consist of programming labs.

Pre-requisites Familiarity with linear algebra.

Syllabus

1. Introduction
2. CSS codes and simple examples
3. QEC codes and stabilizer formalism
4. Knill-Laflamme theory of quantum-error-correcting codes
5. Toric code and generalization
6. Decoding the toric code
7. Lab: Decoders
8. Lab: Fault-tolerance and syndrome extraction circuits

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