Intro to Quantum Error Correction

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1 Introduction

The purpose of this note is to help introduce quantum error correction [QEC] and (especially) fault-tolerance to people who are not familiar with quantum mechanics, or quantum computing, such as:

- undergraduates,
- electrical/computer/software engineers,
- experimental physicists now trying to implement QEC, who have missed such an introduction.

My goals in writing this note are:

- to keep it short, at the cost of completeness,
- to refer to longer/superior works where possible (often),
- to frequently compare "scary quantum" processes with their classical equivalents, to help de-mystify QEC.

[Insert usual caveat about imprecise notation, i.e.: these notes are free, and you get what you pay for.]

I begin in the following section with an explanation of why error correction is necessary, moving on to describe the difference between error-correction and fault-tolerance, before moving on to the most popular elements of QEC theory (stabilizer codes $\mapsto$ CSS codes $\mapsto$ homological codes $\mapsto$ the surface code).

2 Why Error Correction?

If you meet a software engineer in the street, the need for error correction may not be obvious. In the life of a computer programmer, errors are things caused exclusively by people, and careful thinking and good practices are required to prevent, detect and correct them. [Maybe there's a repetition code at work here, especially with `diff`, but that is an analogy for another day.]

2.1 Fault Tolerance

3 The Stabilizer Formalism in a Nutshell

3.1 CSS codes

3.2 Homological Codes

3.3 The Surface Code