Computational Analysis of the Thermodynamic Properties of Qubits in Open Quantum Systems using Full Counting Statistics

Popular Science Companion

Alexander Davidson Bryan

Computers have improved many areas of our lives. They allow us to focus on more human tasks, leaving the menial calculation work to the machines. However, computers as we know them are somewhat limited. There are some tasks which they are not capable of performing in a timely manner as everything must be calculated in small, definite steps. Quantum computers allow for new types of algorithms that are not possible with classical computers, which allow for more efficient computation of these difficult tasks. This is due to some of the unique attributes of nature such as superposition and entanglement, that quantum mechanics has allowed us to study.

The idea behind a quantum computer is centred around the idea of a qubit. The qubit is the quantum equivalent of a bit in a classical computer, however unlike the normal bit, which can have only values of 0 and 1, the qubit can be in a superposition of both these states. Additionally if there are more qubits, they can become entangled. This means that you cannot describe completely the properties of each of the qubits on their own, but instead have to talk about all the qubits as a whole in order to describe it properly. It is these properties which allow for the kind of computations which cannot be performed with normal classical bits.

But if such computers are so great, why haven't we made them yet? The issue is that for quantum computers to work correctly, they need to utilise these quantum effects, which are very difficult to control. Usually when a quantum sized object comes into contact with a large complex system, such as humans, their quantum properties dissipate rapidly. Much effort has gone into attempting to understand and minimise these effects, which is the main goal of this thesis.

In this thesis a (classical) computer simulation of this decoherence process for a qubit under specific circumstances has been created. There were many attempts to cajole information from the simulation, and the hope is to use the knowledge gleaned from these simulations to improve designs for quantum computers in the future.

A Layman's explanation of the title were is given here: Computational analysis simply refers to the fact that this is a computer simulation, the thermodynamic properties of a qubit are to do with the probabilities for it to be in the zero state, or the one stat as described earlier, open quantum systems are small systems interacting the large complex ones and full counting statistics is a method of getting more information out of the simulation.

Quantum computers will probably become a reality someday. But even if they don't, classical computers could benefit from this kind of knowledge as well. As processors become smaller, they are affected more and more by quantum mechanics. Understanding how the very small acts when the very large is attempting to control it will be very important as we approach a new scale of transistor, which is effected by, and sometimes utilises quantum mechanics.