Quantum Computing Projects

Simulate Quantum Computation on Classical Computers

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Quantum computing and quantum information processing will open up all sorts of new possibilities for new algorithm developments and are **set to revolutionise the way we both think about and do computing**. Unfortunately right now it is very hard to build a real quantum computer except one with only simple capabilities. However we can simulate the actions of a quantum computer on a classical (ordinary) computer. Actually, even this is hard and it is difficult to achieve the numerical accuracy and stability to simulate anything other than a very small quantum computer. Nevertheless we can learn some amazing things about quantum computation and investigate how it may become feasible to build real and practically sized quantum computers by experimenting with simulations.

This project involves **experimenting with a range of simple quantum systems** and **developing interactive programs to compute their properties** and to **investigate the numerical stability of the algorithm**s used. These ideas are ultimately to be incorporated into a quantum computer simulator that is capable of simulating around 20 to 30 **quantum bits or "qubits."** Study of numerical limiting properties of this system may lead to ideas for improving practical quantum computers.

A first step is to experiment with numerical solutions to well-posed quantum systems. The project will start by using well-established numerical techniques to find the eigen-values and eigen-functions (ie the "allowable solutions") of the time independent Schrödinger equation. This is a partial differential equation that specifies the allowable quantum states of a particular system. It will be useful to develop a simulation program that not only lets us look for solutions interactively but which also allows us to visualise them and their properties. **This part is achievable at undergraduate or honours level**. There is scope for looking at two-dimensional problems as well as toy one-dimensional systems at this level.

More sophisticated work will look at numerical stability properties of numerical algorithms for solving the Schrödinger equations more generally as well as at other ways of expressing solutions (as matrices for example.) Further work will involve setting up metrics to quantify the numerical stability of solutions as they are found, and to look at ways of improving their stability or at least quantifying limits in it. These ideas then need to be incorporated into a quantum computation simulator. A limited simulator is already built using C++ and various libraries. There is other work ongoing to instrument this system for stability properties and to **incorporate different qubit representations**. There is **scope for several PhD topics** in this work: parallelising the algorithms; development of a simulation language; and visualisation of quantum algorithms, as well as the stability ideas described above.

This project represents an opportunity to join in ongoing research activity at a student-project level. Parts of this project could be carried out at **undergraduate, honours, masters or PhD level** with obviously more work required to implement more of the aspects of the system at higher levels of study. These projects would suit a programmer with interests in scientific and numerical algorithms.

Software development work for this project could be carried out using C/C++ or Java. It would be best if you have taken and passed papers 159.234 (and its pre-requisite papers) to have any reasonable chance of carrying out enough work on this project at undergraduate or honours level. You also need to have done calculus at senior high-school level or preferably at 1st year University level. It would help if you have some senior high-school or 1st year University level physics experience too.

Some aspects of quantum computation will be covered in 159.732 in semester 2 of 2006. Parts of this project might therefore be of particular interest to students taking Computer Science Honours this year. Forthcoming material associated with this paper will support this project. These are not trivial projects but may provide grounding for anyone interested in a career at the very fore-front of computer science.