Term Project

Quantum Information Systems Wesleyan University Spring 2017

Introduction

In lieu of a final exam, students will complete a term project in which they research a topic of their choice related to quantum information systems. The main aspects of this project are as follows:

- Students may work alone or in groups of up to three.
- Students may choose their own research topic, subject to instructor approval.
- Students will prepare both a classroom presentation and a written report of their findings.

Topics

Students should choose a topic that interests them related to quantum information systems. A list of suggested topics appears at the end of this document, but is not intended to be comprehensive or normative. Students are encouraged to pick a topic related to their own academic or personal interests.

Groups

Students may, but need not, work in small groups. Students interested in researching the same topic should consider either working together in a group, or else coordinating their separate presentations to avoid duplication. The Instructor will inform student whose topics are closely related of any potential overlap. Students working together in a group are jointly responsible for the outcome of their project.

Presentations

In-class presentations will commence on May 1. As that date approaches, the instructor will schedule individual presentations for specific dates. It is anticipated that presentations will fill most of the last two weeks of our course meetings.

Each presentation should last approximately 20–25 minutes per person. Teams with more members are therefore afforded more time to make their presentations. Each team member should participate meaningfully in the presentation. At the end of each presentation there will be time for questions from the audience.

Written Reports

In addition to the classroom presentation, students will submit a written report. The report should be submitted as an electronic document (preferably in pdf format) no later than the last day of the semester, May 10.

There is no length requirement, but the written report should clearly describe the topic researched by the student(s). This includes an introduction containing context and motivation, a clear explanation of the key issues and facts, a discussion of examples or applications of the topic, proper citations of sources consulted, and a bibliography.

Evaluation

Research projects will be evaluated for both ambition and execution. The classroom presentation and written components will be given equal weight. All team members working together on a project will receive the same grade.

Schedule

- Please inform your instructor of your proposed topic and collaborators no later than April 17.
- We will agree a schedule for presentations together in class on April 26. Willingness to present toward the beginning of the allotted days will be looked on favorably.
- Presentations will commence at the class meeting of May 1, and continue though the following class meetings as needed. If substantial extra time remains after the presentations are concluded, the instructor will try to think of something interesting to talk about.
- Written reports are due via email attachment no later than midnight on May 10.

Possible Topics

Entanglement measures How can we quantify how entangled a system is? People have proposed several ways.

Mixed states When part of a system becomes entangled with the outside world we can describe its behavior only statistically.

Bloch sphere A geometric representation of the state space of a qubit.

Quantum error correction How can we detect and correct errors in qubit states without directly measuring those states?

Quantum algorithms Quantum algorithms differ from classical ones in making essential use of superposition and entanglement. Some famous quantum algorithms include those for list searching and prime factoring.

Quantum complexity classes The line separating "easy" from "hard" problems is different for quantum algorithms than for classical ones. For example, tasks like factoring appear to allow for exponential speed-ups when performed on a quantum computer. How can we characterize the quantum complexity of a given problem?

Quantum cryptography Entanglement permits new ways to secure communications against unwanted interception. In some cases, resistance to certain classes of attacks attains the status of a physical law.

Quantum simulation One of the founding ideas about quantum information systems is that "quantum simulates quantum". A very promising application for quantum computing is modeling nuclear, chemical and biological processes whose complexity overwhelms digital analysis.

Physical realizations How can we build a quantum computer as a physical system? Lots of people are working on different approaches.

Circuit optimization Because there are so many interaction laws between qubit operators, it is often possible to optimize a quantum circuit to a much simpler one, but how can we find such optimizations?

Higher-level quantum programming languages In this course we have discussed quantum logic, which is the "assembly language" of quantum computing. How can we abstract from primitive operators to a higher-level language suitable for large-scale programming?

Formal methods People are working on creating tools to mechanize and automate reasoning about quantum information systems. These include online proof assistants such as *globular* and *quantomatic*.

Toy theories One of the best ways to understand the theory of quantum information systems is to study other theories that share some, but not all, of its properties.