Spring 2017 CS 410/510 - Intro to Quantum Computing

About

- **Instructor**: Fang Song @ FAB 120-07. Email: fsong“AT”pdx.edu.
- **Lectures**: Tu/Th 2:00 - 3:50 pm @ Fourth Ave Building 47.
- **Office hours**: Tuesday/Wednesday 4:00 - 5:00pm, or by appointment.
- **Course webpage**: http://www.fangsong.info/teaching/s17_4510_qc/. Please check regularly for updates and announcements.
- A **resource page** http://www.fangsong.info/teaching/s17_4510_qc/resource/ with useful materials related to the course.

Course Description

The law of quantum physics is revolutionizing what feasible computation may look like, and a new paradigm of **quantum computing** has been emerging. Quantum computers can solve some fundamental problems efficiently, sometimes expoentially faster than what we can on a classical computer. Numerous promising applications are being developed such as in chemistry, machine learning, and especially cryptography (the Internet will be **broken** by quantum attackers!).

In this course, we will study the basic principles and techniques of quantum computing, and discuss some of the applications. The goal is to equip you with the essential tools to appreciate, further explore and (even better) devote to this exciting research area. Tentative topics include: quantum states and circuits, entanglement, quantum algorithms (e.g., Grover's search and Shor's factorization algorithms), quantum complexity theory, quantum error-correcting codes, and applications in cryptography.

Recommended texts (not required)

- Quantum Computing since Democritus by Scott Aaronson, based on his lectures (Fall 2006 at UWaterloo).
- An Introduction to Quantum Computing by by Phillip Kaye, Raymond Laflamme, Michele Mosca.
- Quantum Computer Science: An Introduction by David Mermin, based on his lectures (Spring 2006 at Cornell).

Prerequisites

Maturity in algorithm analysis and mathematics (espeically linear algebra, basic probability thoery and group thoery). Quantum mechanics is helpful, but **NOT** required. This course will be theory-oriented involving reading and writing lots of mathematical proofs. I **strongly** recommend you skimming through the first few lectures of these notes by Watrous PDF and by Vazirani link to get a sense what we will be dealing with. If you feel uncertain, please email me to set an appoinment, and I'd be happy to discuss with you.

Main topics

- Part I (~1 week): **Basics**. Qubit, quantum circuit model.
- Part II (~4 weeks): **Quantum algorithms**
  - quantum query model, Deutsch and Deutsch-Josza algorithms
  - Simon's problem, Quantum Fourier Transform
  - phase estimation, order finding, quantum factorization algorithm
  - Grover's search and lower bound
- Part III (~2 weeks): **Quantum information theory**

  - entanglement, Bell's inequality
  - quantum information formalism
  - entropy, Holevo's theorem
  - quantum error correction codes
- Part IV (~2 weeks): **Quantum complexity theory & topics**
  - BQP, QMA
  - quantum cryptography and post-quantum crypto

Policy

- **Grading Policy**: Homework 50%, Project 40%, Participation 10%.
- **Homework**: You must turn in hard copies of your assignments before the class begins on the due date. The solutions must be intelligible. I encourage you to type your homework with Markdown or Latex (and submit the printouts). *Late homework* is acceptable, but there will be a penalty of 20% (<1 day), 40% (1-2 days), 60% (2-3 days), and 100%(>3 days).
- **Collaboration** in small group on homework problems is *highly encouraged*. However, each person must write up their solutions independently. For each problem that you have collaborated with others, you must list the names of your collaborators.
- **Course project**: you will form a group of 3 people maximum and explore research topics related to this course. You may choose to survey a specific topic or take on original research problems. It will be evaluated progressively: proposal (5%), mid-term report (5%), oral presentation (15%), and final report (15%). Details such as suggested topics will be provided after the class begins.
- **Academic integrity**: Students will be responsible for following the PSU Student Conduct Code.
- **Students with disabilities**: If you need academic accommodations, you should register with the Disability Resource Center and notify the instructor immediately to arrange for support services.