ECE 492-054/592-100
Signal Processing Tour of Quantum Computing

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Objective or Description: This course is envisioned to provide students an in-depth understanding of some quantum computing algorithms through the lens of signal processing.

Prerequisites:

1. As suggested by the course's name, it will be advantageous for students to be familiar with signal processing or quantum computing. However, seeing that the number of students who have both backgrounds is limited, we will review these materials during the first part of the course.
2. Students must be familiar with linear algebra (e.g., Math 305), probability and statistics (ST 371).
3. Programming proficiency, for example in Matlab or Python, will be needed.
4. It will be helpful (but not required) for students to be familiar with linear systems (ECE 301), undergraduate signal processing basics (ECE 421), mathematical transforms such as Fourier, and group theory (Math 407).

Textbook: The topics covered in the course do not correspond to any single textbook, and we will instead mix and match topics from various sources. Indeed, a possible longer-term objective of the course is to create new educational resources, possibly including a textbook.

Topics: As a new and thus somewhat experimental course, it is difficult to predict in advance precisely what we will cover. The following list should be interpreted as a roadmap, and we may veer a bit away from our planned route as we "tour" these topics.

1. Motivation and Introduction.
2. Mathematical basics: complex numbers, linear algebra, tensor products.
3. Quantum computing basics: state spaces, quantum evolution, measurement, qubits, single qubit gates, multi-qubit gates, entanglement. Deutsch's algorithm.
4. Signal processing basics: discrete time signals and systems, discrete time Fourier transforms, frequency interpretation of linear time invariant systems.
5. Hadamard transform: finding XOR function patterns, Deutsch-Jozsa algorithm, Bernstein-Vazirani algorithm.
6. Computation of Fourier transforms: Fast Fourier transform (classical) and quantum Fourier transform.
7. Phase estimation: quantum phase estimation, classical spectral estimation, noisy spectral estimation.

Grading: The core grade components will be Homework 40%, Final project 30%, and Exam 20%.
We will allocate 10% of the grade for students to pursue various quantum interests. One "quantum interest" will be to attend / summarize / critique seminars in topics related to the course; we suggest talks in the NC State Quantum Hub Workshop [January 2023] or Triangle Quantum Computing Seminar. Another "quantum interest" style contribution would be for a student to record educational modules and put them online.
In a course co-listed at the 400- and 500- levels, we will differentiate between undergraduate and graduate students by having somewhat elevated expectations when it comes to graduate students. For example, an undergraduate final project could be summarizing a paper briefly. In contrast, we expect graduate students to demonstrate some novelty.

Cross-listing in other departments: The course will be advertised among faculty members involved in quantum computing in other departments: math – Profs. Bojko Bakalov and Moody Chu; physics – Lex Kemper; computer science – Frank Mueller and Jianqing Liu; chemistry - Elena Jakubikova.

Include anything else that is unique to the course - this information will be posted on the ECE Current Graduate/Undergraduate Student Portals for all students to view

Students who are potentially interested in the course may want to view Prof. Baron's recent tutorial on quantum computing: https://youtu.be/CUh4JT9w8ww
Inquiries to Prof. Baron will be welcome!