Introduction to Quantum Advantage

CSCI-C 290 (5165) and CSCI-A 590 (14034) 6W2 Summer 2024

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This is a hybrid (that is, in-person, remote synchronous and asynchronous) class. The class starts on June 17 and ends on July 26. The class meets in Luddy Hall, Bloomington campus (BLIF) 1019. Lectures will be broadcast over Zoom and recorded. Meeting times are MTWRF (so, daily) from 8:45-10am. Office hours are via Zoom throughout the day, every day. There's a script[1] on the class website[2] that can be used to make appointments with Adrian. About 40 time slots (each 15-20 minutes long) are available daily for office hours including weekends.

The class is structured around six cases of Quantum Advantage:

- Superdense Coding
- Grover's Algorithm
- Bernstein-Vazirani
- Deutsch-Josza
- Quantum Teleportation
- The GHZ Game

The textbook for this class[3] is "The Little Qubitzer":

https://legacy.cs.indiana.edu/~dgerman/2024/sigcse/the-little-qubitzer.pdf

It is based on Terry Rudolph's "Q is for Quantum":

https://www.qisforquantum.org/

Copies of these books will be distributed free of charge in class. These materials will be supplemented with Martin Laforest's math primer entitled "The Mathematics of Quantum Mechanics" available both locally[4] and from IQC[5]:

https://uwaterloo.ca/institute-for-quantum-computing/download-qcsys-math-primer/qsys-math-primer

Another textbook that we will use in this class is Thomas Wong's "Introduction to Classical and Quantum Computing" a book available for free from:

https://www.thomaswong.net/introduction-to-classical-and-quantum-computing-1e4p.pdf

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[1] http://silo.cs.indiana.edu:31415/cgi-bin/sum2024/schedule

[2] https://legacy.cs.indiana.edu/classes/c290-quantum

[3] We will be using Python in Google Colab and Qiskit throughout.

[4] https://legacy.cs.indiana.edu/~dgerman/2020/boot-camp/mathematics_qm_v21-martin-laforest.pdf

[5] https://www.youtube.com/playlist?list=PLBRgytHojT9ZASzmyaaZIPta27nmhAevk

There will be many other materials (books, papers, videos) I will provide for your reference that you will be able to look through for free while you are taking this class.

Eight Simple Rules

I once wrote a material[6] for a 6W1 Summer C200. I will try to prepare a similar material for this class and post it by the first day of class(es). Anticipating, I can say that the topics we will discuss in order will start with "The Little Qubitzer" because it's the simplest approach that does not require any sophisticated mathematics, as explained here:

https://meetings.aps.org/Meeting/MAR24/Session/K61.4

The goal, though, is for you to eventually make the transition to the standard formalism for Quantum Information Science. Some students take this class as a boot camp for our MS in QIS program. For them the goal is to function successfully in P555 which is the first class in the program. Textbooks used for that class in the last three years:

https://qubit.guide/qubit_guide.pdf

https://www.amazon.com/Quantum-Computation-Information-10th-Anniversary/dp/1107002176

https://www.amazon.com/Quantum-Computer-Science-David-Mermin/dp/0521876583/

Electronic versions of the these books (and more) can be readily found on the Internet and I will share with you my copies while you are enrolled in my class. We will discuss and work out together a variety of problems and exercises in class. Some examples are listed here:

https://legacy.cs.indiana.edu/classes/c290-quantum-dgerman/thq.pdf

There will be three quest lectures by Maria Violaris (Oxford University, UK) on July 10, 17, 24. She will present "Quantum Thought Experiments Implemented in Qiskit":

https://www.youtube.com/playlist?list=PLOFEBzvs-VvoQP-EVyd5Di3UrPPc2YKIc

Maria is a PhD student at Oxford, working with David Deutsch on the foundations of quantum information science. Her guest lectures will bring home the essence of the field and the very interdisciplinary aspect of it in a class in which we will have studied (twice): superposition, phase, interference, entanglement, quantum gates and quantum circuits, the six cases of quantum advantage listed above including entanglement swapping, Shor[7], VQE and QAOA.

There will be six take-home exams, one for each week, to be submitted online and defended in person with the instructor (Adrian German) in a short weekly meeting via Zoom.

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[6] https://legacy.cs.indiana.edu/~dgerman/2020/c200-eight-simple-rules.pdf
[7] https://legacy.cs.indiana.edu/~dgerman/2020/boot-camp/qc-high-2e-with-cover.pdf