State University of New York Polytechnic Institute
CS 538 : Noisy Intermediate-Scale Quantum Algorithms

Instructor:	Dr. Chen-Fu Chiang
Semester:	Fall 2022
Time:	MW 6:00 pm - 7:15 pm
Location:	Kunsela Hall A133
Office Hours:	MW (My office) : 2:00 pm - 4:00 pm
	Online: T: 10:30 am - 11:30 am
	https://us.bbcollab.com/guest/90a52935d66d408b813d43abe3f22a56
Office :	Location: Kunsela C225 || Phone: (315) 792-7379
Email:	chiangc@sunyply.edu (best way to reach me)
URL:	http://www.cs.sunyit.edu/∼chiangc

References

1. Quantum Computation and Quantum Information ||Cambridge University Press, ISBN-10: 9781107002173
2. Noisy Intermediate-Scale Quantum (NISQ) algorithms https://arxiv.org/pdf/2101.08448.pdf

Useful Online Basic Reference & Lab for Lecture Notes

1. Ronald de Wolf https://homepages.cwi.nl/∼rdewolf/qcnotes.pdf
2. Andrew Childs https://www.cs.umd.edu/∼amchilds/qa/qa.pdf
3. IBM Quantum Lab https://quantum-computing.ibm.com/lab

Note

1. This course is self-contained and students are encouraged to work together in study groups.
2. It is preferred that the students have some background in matrix linear algebra and probability.

Course Description

This is a more research oriented course. Quantum information and computation exploits quantum mechanical rules to process information. As a new branch of interdisciplinary science, it has both fundamental and technological implications. As the experimental advancement towards realizing such a quantum device will take decades of research, noisy intermediate scale quantum (NISQ) already exists. The noisy qubits (not error-corrected) can only perform imperfect operations in a limited coherence time. Quantum algorithms under such constraints have been proposed to leverage the limited resources to perform classically challenging tasks in physics, machine learning, quantum chemistry and combinatorial optimization. This course is designed to introduce graduate computer science students (or advanced undergraduate students) to these algorithms and their applications.

Student Learning Outcomes

Upon completion of this course the student should be able to:

- Describe the Foundations of Quantum Systems
- Interpret the Quantum Circuit Model
- Explain the Physical Principles of Quantum Computation and Its Current Limitations
- Apply the Core and NISQ Quantum Algorithms

Topics

Each topic should last for 1 or 2 lectures, based on the progress in the class. The instructor will speed up or slow down the lectures according to students' understanding of the material. It is recommended that the students read the material (and the original papers) ahead before the lecture. Topics from 1 to 5 are the basic fundamentals. Topics from 6 to10 are the more advanced theoretical quantum algorithms. Topics from 11 to 16 are the state-of-the-art NISQ techniques and its applications.

seq #	Topics	seq #	Topics
1	Linear Algebra & the Dirac Notation	2	The Framework of Quantum Mechanics
3	Quantum Circuit Model	4	Quantum Gates
5	Universal Sets of Quantum Gates	6	Intro to IBM QISKit Software
7	Discrete Quantum Walk (Szegedy)	8	Continuous Quantum Walk
9	Quantum Approximate Optimization Algorithm	10	Intro to Adiabatic Quantum Computing
11	Building Blocks of Variational Quantum Algorithms (Parameterized Circuit)	12	Parameter Optimization (Gradient-based Optimization, Gradient-free)
13	Other NISQ Approaches (Annealing, Boson Sampling, Eigensolver)	14	Theoretical Challenges (Barren Plateaus, Reachability , QAOA)
15	Programming and Maximizing NISQ	16	Applications (Machine Learning, Many-body Physics and Chemistry)

Grading (Tentative)

The lecture format will be the basic mechanism used in the course. Computer demonstrations in the classroom will be used whenever appropriate. Assessment of student performance will use a criterion-referenced model which will include written assignments (30%), regular examinations (midterm 25%), presentation along with a short report regarding either quantum algorithms or implementation via quantum programming languages (20%), and a comprehensive final exam (25%). **Late assignment will not be accepted unless you have made prior arrangements with me**. The acceptable format of your solution will be specified in the assignment. All examinations are closed-book. Percent and Grade :
89.5-100 A 79.5-89.5 B 69.5-79.5 C 59.5- 69.5 D Below 59.5 F
(+/- modifiers will also be used ; for instance, [95.5-100]: A+, [92.5-95.5): A, [89.5-92.5): A-)

Attendance Policy

Attendance and active class participation are required. Be prepared to participate by asking and answering questions during class meetings. Please send me an email if you know you have to miss a class.

Academic Integrity/Policy

Plagiarism and Cheating of any kind on an examination, quiz, or assignment will result at least in an F for that assignment (and may, depending on the severity of the case, lead to an F for the entire course). I will assume for this course that you will adhere to the academic creed of this University and will maintain the highest standards of academic integrity. In other words, do not cheat by giving answers to others or

taking them from anyone else. The code of academic conduct is detailed on the SUNY Poly student handbook. Make-ups are only given under extreme circumstances. I will also adhere to the highest standards of academic integrity, so please do not ask me to change (or expect me to change) your grade illegitimately or to bend or break rules for one person that will not apply to everyone.

Plagiarism Warning

The work you submit must be your own. You will not receive credit for work which is not your own. You may ask others (classmates/friends/instructors) for advice or help regarding the subject matter of a problem set. However, your answers and the actual design, coding, entry, and running of your programs must represent your own work. All sources of ideas that are used in any way (quoted, paraphrased, or summarized), including ideas taken from the text, must be acknowledged in problem set program documentation. Failure to provide proper attribution constitutes academic dishonesty, and it will result in a failing course grade. Substantially identical program submissions by multiple students, even with attribution, may result in a failing course grade to all who submit the same program. Submitting a program written by someone else, even with attribution, is strictly prohibited and will result in a failing course grade. Students are further reminded that it is their responsibility to take reasonable precautions to prevent copying of their work by other students and that there are now criminal penalties for computer trespass and computer tampering.

Cancellation of Classes Due to Inclement Weather or Other Emergency

SUNY Poly has a 24-hour hotline to inform students, faculty and staff when severe winter weather prompts the cancellation of all classes. On-campus, you can call the "Snowline" by dialing ext. 7669 ("SNOW"). Off-campus, Snowline can be reached by calling 315-792-7385. Snowline cards are available at various locations on campus. In the event of severe weather, Snowline will announce only the cancellation of ALL classes. The cancellation of all classes will also be posted online, at sunypoly.edu, and will be broadcast on radio and television stations in the Utica-Rome, Syracuse, and Albany areas. Individual class cancellations are always available at sunypoly.edu/apps/canceled_classes .

Accommodations for Students with Accessibility Needs

Accommodations for Students with Accessibility Needs Your access in this course is important to me. In compliance with the Americans with Disabilities Act of 1990 and Section 504 of the Rehabilitation Act, SUNY Polytechnic Institute is committed to ensuring comprehensive educational access and accommodations for all registered students seeking access to meet course requirements and fully participate in programs and activities. Students with documented disabilities or medical conditions are encouraged to request these services by registering with the Office of Student Accessibility Services. Please request accommodations early in the semester, or as soon as you become registered with the Office of Student Accessibility Services, so that we have adequate time to arrange your approved academic accommodation/s. Once Accessibility Services creates your accommodation plan, it is your responsibility to provide me a copy of the accommodation plan.

If you experience any access barriers in this course, such as with printed content, graphics, online materials, etc., reach out to me or Accessibility Services right away. For information related to these services or to schedule an appointment, please contact the Office of Student Accessibility Services using the information provided below.

Office of Student Accessibility Services
SAS@sunypoly.edu
(315) 792-7170

Utica Campus