Polytechnic School of Engineering, NYU
CS 6033: Design & Analysis of Algorithms
Course Syllabus
Fall 2021

Prof: Linda Sellie
Office Hours: Thursday 2:00 - 4:00 and by appointment. *Office:* 370 Jay Street, room 848
Contact Information: Please send a message to me on NYU Brightspace
Class communication: We will use the discussion course site on Brightspace. Assignments will be posted on NYU Brightspace, but you will turn in your assignments on Gradescope

Catalog description: Review of basic data structures and mathematical tools. Data structures: priority queues, binary search trees, balanced search trees. B-trees. Algorithm design and analysis techniques illustrated in searching and sorting: heapsort, quicksort, sorting in linear time, medians and order statistics. Design and analysis techniques: dynamic programming, greedy algorithms. Graph algorithms: elementary graph algorithms (breadth-first search, depth-first search, topological sort, connected components, strongly connected components), minimum spanning trees, shortest paths. String algorithms. Geometric algorithms. Linear programming. Brief introduction to NP-completeness.

Prerequisites: You *must* have taken these courses to take this course.

- CS5403: Data Structures and Algorithms, or equivalent knowledge of fundamental data structures.
- CS6003: Foundations of Computer Science, or equivalent knowledge of discreet mathematics for computer science.
- A programming course beyond "Introduction to Programming".

Additionally, you should not take this course if you have taken a similar course with a B or better grade.

Textbook: Cormen, Leiserson, Rivest, and Stein, Introduction to Algorithms, 3rd Edition, MIT Press, 2009; ISBN-13: 9780262033848; ISBN: 0262033844. It is known as CLRS.

We have free access to CLRS on BOOKS24x7 on the NYU library web site
`http://library.nyu.edu`, search for books24x7).

Approximate Grading Scale Your final grade will be determined roughly as follows: homework assignments 10%, online quizzes 5%, attendance 5%, midterm exam 40%, and final exam 40%. (Extra consideration in determining your grade will be based by your exam scores, especially the final exam. If you do poorly on the midterm, please contact me and I can potentially give more weight to your final exam.)

To make it easier to grade, typed homework assignments will be given a 5 point bonus. Any homework assignment that is difficult to read will *not be graded.*

The online quizzes will focus on the prerequisite material needed for the course. We will have online quizzes (approximately weekly in the first part of the semester and more infrequently towards the end of the semester). You can see the topics of the online quizzes in the schedule below by looking at the *assumed background material.*

The tentative schedule for the midterm exam is November 02, 2021. The final exam is December 21, 2021.

Attendance at exams is mandatory. Make-up exams will only be given in the case of a emergency, such as illness, which must be documented, e.g. with a doctor's note. See **NYU School of Engineering Policies and Procedures on Excused Absences**. In such cases, you must notify me as early as possible, preferably before the exam is given. If you miss an exam without a valid excuse, you will receive a grade of *zero* for that exam. The exams will be closed book and no notes.

Due to the course's high pace and the fact that this course tends to build on preceding lectures, this course has an attendance as a (relatively small) portion of its grade. If you need an excused absence for any reason, including coronavirus related reasons please contact Deanna Rayment (deanna.rayment@nyu.edu) in the Student Affairs office to get an excused absence. Policy states that it is not my responsibility to evaluate medically related or extended excused absences, and suggests that it is best to resolve those issues in general thru student affairs. Relevant sections of the policy are reproduced below with a link to the full policy document.

Course Work: You are expected to have the appropriate background for the course.

Homework assignments (approximately weekly) will be posted on NYU Brightspace. Clarifications, corrections, and the occasional helpful hint will be posted on the discussion forum on Brightspace. You are responsible for being aware of any information posted there, so you should check it regularly.

For the story-like questions in the homework assignments, we expect you to use several sentences to explain your algorithm and then provide pseudocode. You need to specify what kind of data structure you will use and how you would use it, and give a simple running time analysis. For the coding part, you can use subroutines that appeared in the lecture without rewriting the code (if you modify part of it, please specify your modifications). The critical point is to make sure that the grader can understand your logic. The TA's may provide more details on the Brightspace forum.

Although the homework makes up a relatively small percentage of the final grade and is a lot of work, it is a key component to mastering the course material.

No late homework assignments will be accepted.

Academic Dishonesty: Cheating will not be tolerated. Absolutely no communication with other students is permitted on exams. I advise you that I will seek a F in the course for any cheating on an exam. So, if you copy a single answer from someone else, I will be seeking an F in the course for you. There are possible additional actions at my discretion including involving the CS department and the administration. Cheating disqualifies you from any offers of help.

Please see the university policy: https://engineering.nyu.edu/academics/code-of-conduct/academic-dishonesty

Policy on Collaboration: You may discuss general approaches on how to do the homework assignments with other students. You may work with **one** other student to work out the details of the questions, and to write up the solution. If you work with another student, you **must** put both names and netID's on top of the assignment. Additionally, if you work with a partner, **only one** of you will *submit* the assignment on Gradescope (but both of you are responsible to make sure it was submitted). If you do not have your name on top of the assignment, you will not receive any points for that assignment. If you work together, you must fully understand the work you submit. Your submission must be your (and your partner's) work. If there is any evidence that the work is not yours (and your partner's) work (such as copying from others, from the Internet, paying a third party to carry out the work, etc) it will be considered academic dishonesty. You will receive a 0 for the assignment, you will be reported to the department and the Dean of Student Affairs, and potentially receive a F for this course.(See http://cis.poly.edu/policies/)

APPROXIMATE SCHEDULE Please check for updates during the semester. Lectures slides will be posted on NYU Brightspace a day or two after the lecture. Last semester's slides are already posted on NYU Brightspace. The precise order and content, especially of the later parts of the course, may change. We will work down the list of topics given in the syllabus. The pre-requisites are assumed for this course. Some topics that have been useful for students to brush up on before a lecture are mentioned in the assumed background (this is not a complete list). If an item appears under assumed background - I will assume you know that topic for the rest of the semester. For the background material, the resources listed are for a quick reminder - please consult additional resources if needed.

- **Week 1:** Introduction: What's an algorithm? Why do we want to study algorithms? Termination. Correctness. Performance. How to measure performance of an algorithm? Models of computation, abstract machines. RAM. Best-, worst-, and average-case performance. Review of asymptotic notation: big-O, big-Ω and big-Θ; little-o, and little-Ω. Discuss running time and correctness of Insertion Sort. If we have time, we will discuss the running time of merge sort.

  Assumed background material: asymptotic notation, mathematical induction, insertion sort and merge sort

  Resources: CLRS chapters 1, & 2. Review of asymptotic notation is in CLRS chapter 3.

- **Week 2:** Finish discussing the running time Merge sort. Quickly go over the big-Oh running times of some dynamic set operations on arrays, stacks, queues, linked lists. Discuss ADT of priority queue. Discuss binary heaps: algorithm, running time, correctness, and use in heapsort.

  Assumed background material: concept of abstract data types (ADTs). Common ADTs and how they are implemented: stacks, queues, lists. Geometric series.

  Resources: CLRS pages 147-150 and chapter 6. Review of basic data structures is CLRS pages 229-231, and chapter 10. Review of geometric series page 1147

- **Week 3:** Dictionaries ADT. Hashing. Running times for different approaches for the dictionary ADT. Universal hashing, perfect hashing

  Assumed background material: hashing (linear probing hashing, separate chaining hashing, load factor), basic probability, linearity of expectation, modular arithmetic, indicator random variable

  Resources: CLRS chapter 11. Review of linear probing hashing and separate chaining hashing in CLRS chapter 11. Review of basic math background: indicator random variable in section 5.2 (pages 118-120), binomial coefficients page 1185, expected value of a random variable and linearity of expectation page 1197-1199, modular arithmetic page 54

- **Week 4:** Dictionaries ADT. Balanced search trees (tentatively, 2-3 trees, 2-3-4 trees, and more generally (a, b)-trees, red-black trees).

  Assumed background material: binary search tree (traversing a tree - inorder/postorder/preorder, inserting into a tree, and properties of a tree - height/depth/size/etc), logarithm function

  Resources: CLRS chapter 13. Review of binary search trees in CLRS chapter 12.

- **Week 5:** Augmenting a balanced search tree and B-trees, External memory model

  Assumed background material: recursion, matrix multiplication

  Resources: CLRS chapters 14 & 18

- **Weeks 6 & 7:** Divide-and-conquer algorithms. Review of recurrences and how to solve them. Master's theorem. Binary search. Mergesort. Quicksort. Median and order statistics. Deterministic linear-time selection. Fast integer multiplication (Karatsuba's algorithm). Fast matrix multiplication (Strassen's algorithm). Closest-pair problem. Chapter 4, 7, 9 and 33.4.

  Assumed background material: Quick sort, adding/multiplying binary numbers

  Resources: CLRS chapter 4

  Please note, the notation used in the slides is not the same as is used in the book. In the slides, S is used as a set of keys, and S_j is the set of keys that mapped to the jth index. In the book, S_j is the jth secondary hash table in perfect hashing.

- **Weeks 8 & 9:** Graph algorithms: elementary graph algorithms (breadth-first search, depth-first search, topological sort, connected components, strongly connected components), minimum spanning trees, shortest paths. Some graph algorithms will be presented later in the course as illustrations for different algorithm design paradigms. Union Find.

  Assumed background material: a basic understanding of graphs (nodes, edges, ...) an understanding of depth first search (DFS) and breadth first search (BFS)

  Resources: CLRS page 588 and chapters 21, 22 & 23. Background material resources: section B.4 pages 1168-1172

- **Weeks 10 & 11:** Dynamic Programming: Rod cutting. Matrix chain product. Longest common subsequence. Optimal binary search trees. Shortest path problems in graphs. Transitive closure.

  Resources: CLRS chapters 15 & 24.

- **Week 12:** Greedy algorithms: Activity selection. Huffman coding.

  Resources: CLRS chapter 16.

- **Week 13:** Undecidability and fundamentals of NP-completeness (both very briefly; one lecture).

  Resources: CLRS chapter 34.

Moses Center Statement of Disability

If you are student with a disability who is requesting accommodations, please contact New York University's Moses Center for Students with Disabilities (CSD) at 212-998-4980 or mosescsd@nyu.edu. You must be registered with CSD to receive accommodations. Information about the Moses Center can be found at www.nyu.edu/csd. The Moses Center is located at 726 Broadway on the 3rd floor.

NYU School of Engineering Policies and Procedures on Academic Misconduct

The complete Student Code of Conduct can be found here: `https://www.nyu.edu/registrar/calendars/university\protect\discretionary{\char\hyphenchar\font}{}{}academic-calendar.html#1198`

1. **Introduction:**
   The School of Engineering encourages academic excellence in an environment that promotes honesty, integrity, and fairness, and students at the School of Engineering are expected to exhibit those qualities in their academic work. It is through the process of submitting their own work and receiving honest feedback on that work that students may progress academically. Any act of academic dishonesty is seen as an attack upon the School and will not be tolerated. Furthermore, those who breach the School's rules on academic integrity will be sanctioned under this Policy. Students are responsible for familiarizing themselves with the School's Policy on Academic Misconduct.

2. **Definition:**
   Academic dishonesty may include misrepresentation, deception, dishonesty, or any act of falsification committed by a student to influence a grade or other academic evaluation. Academic dishonesty also includes intentionally damaging the academic work of others or assisting other students in acts of dishonesty. Common examples of academically dishonest behavior include, but are not limited to, the following:

   (a) Cheating: intentionally using or attempting to use unauthorized notes, books, electronic media, or electronic communications in an exam; talking with fellow students or looking at another person's work during an exam; submitting work prepared in advance for an in-class examination; having someone take an exam for you or taking an exam for someone else; violating other rules governing the administration of examinations.

   (b) Fabrication: including but not limited to, falsifying experimental data and/or citations.

   (c) Plagiarism: intentionally or knowingly representing the words or ideas of another as one's own in any academic exercise; failure to attribute direct quotations, paraphrases, or borrowed facts or information.

   (d) Unauthorized collaboration: working together on work meant to be done individually.

   (e) Duplicating work: presenting for grading the same work for more than one project or in more than one class, unless express and prior permission has been received from the course instructor(s) or research adviser involved.

   (f) Forgery: altering any academic document, including, but not limited to, academic records, admissions materials, or medical excuses.

NYU School of Engineering Policies and Procedures on Excused Absences

– complete policy here `https://engineering.nyu.edu/campus-and-community/student-life/office-student-affai policies#chapter-id-30199`

1. Introduction: An absence can be excused if you have missed no more than 10 days of school. If an illness or special circumstance has caused you to miss more than two weeks of school, please refer to the section labeled Medical Leave of Absence.
2. Students may request special accommodations for an absence to be excused in the following cases:
   - Medical reasons
   - Death in immediate family
   - Personal qualified emergencies (documentation must be provided)
   - Religious Expression or Practice

Deanna Rayment, deanna.rayment@nyu.edu, is the Coordinator of Student Advocacy, Compliance and Student Affairs and handles excused absences. She is located in 5 MTC, LC240C and can assist you should it become necessary. NYU School of Engineering Academic Calendar – complete list `https://www.nyu.edu/registrar/calendars/university-academic-calendar.html#1198` If you have two final exams at the same time, report the conflict to your professors as soon as possible. Do not make any travel plans until the exam schedule is finalized. Also, please pay attention to notable dates such as Add/Drop, Withdrawal, etc. For confirmation of dates or further information, please contact Susana: sgarcia@nyu.edu