NYU Tandon School of Engineering
CS 6033: Design & Analysis of Algorithms
Course Syllabus
Fall 2024

Prof: Linda Sellie

Office Hours: Thursdays, 4:45 p.m. to 6:45 p.m. Please note, I may be slightly delayed if I need to address questions after the Thursday section of the class. If you plan to attend office hours, please arrive before 6:00 p.m. to ensure access to the 8th floor.

Office: 370 Jay Street, Room 848

Contact Information: Please send messages via NYU Brightspace.

Class Communication: General announcements will be posted on NYU Brightspace. For class discussions, we will use EdStem. Assignments will be posted on NYU Brightspace, but submissions should be made through 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, 4th Edition, MIT Press (ISBN:978026204630
It is known as CLRS.

We have free access to CLRS 4th edition on the NYU library web site
`http://library.nyu.edu`)

Grading Overview: Your final grade will be determined as follows:

- Homework assignments: 5%
- Online quizzes: 5%
- Midterm exam: 45%
- Final exam: 45%
- In-person participation: 2% extra credit

Extra consideration will be given to your exam scores, particularly the final exam. I will calculate your final letter grade in two ways:

1. Using the breakdown described above.
2. By giving more weight to your final exam score and less weight to your midterm score.

You will receive the higher of the two letter grades.

Any homework assignment that is difficult to read will *not be graded.*

Online Quizzes: The online quizzes will primarily cover prerequisite material necessary for the course. These quizzes will be given approximately weekly during the first part of the semester and less frequently towards the end. The topics of the quizzes correspond to the *assumed background material* listed in the schedule below.

Exam Dates:

- **Midterm Exam:** Date to be determined.
- **Final Exam Dates:**
  - **Tuesday Section:** December 17, 2024
  - **Thursday Section:** December 19, 2024

Exam Policies:

- **Attendance:** Attendance at exams is mandatory. Make-up exams will only be given in the case of documented emergencies, such as illness. Documentation (e.g., a doctor's note) must be provided to Deanna Rayment. Refer to the **NYU School of Engineering Policies and Procedures on Excused Absences** for more details.
- **Notification:** Notify me as early as possible, preferably before the exam, if you need to miss an exam. Without a valid excuse, a missed exam will result in a grade of *zero*.
- **Exam Conditions:** Exams will be closed book and no notes will be allowed.

Participation and Attendance: Due to the fast-paced nature of the course, participation is a bonus portion of the grade. If you require an excused absence for any reason, including coronavirus-related reasons, please contact Deanna Rayment (deanna.rayment@nyu.edu) in the Student Affairs office. It is not my responsibility to evaluate medically related or extended excused absences; these should be handled through 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 will be posted approximately weekly on NYU Brightspace. Clarifications, corrections, and the occasional helpful hint will be posted on the discussion forum on EdStem. You are responsible for staying informed about an updates posted there, so please check it regularly.

For the story-like questions in the homework assignments, you should:

- Use several sentences to explain your algorithm.
- Provide pseudocode.

- Specify the type of data structure you will use, how you will use it, and include a simple running time analysis.

For the coding portion, you may use subroutines covered in the lectures without rewriting the code. If you modify any part of a subroutine, please clearly specify the changes. The key is to ensure that the grader can easily follow and understand your logic. Teaching assistants (TAs) may provide additional details on EdStem.

Note: All running times should be considered worst-case unless otherwise specified. Please use only the data structures discussed in class; avoid using data structures from standard libraries of common programming languages. Additionally, use the function names provided during the lectures.

Although 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 under any circumstances. Absolutely no communication with other students is permitted during exams. I must emphasize that any cheating on an exam will result in serious consequences, including receiving an F for the entire course. Even copying a single answer from someone else will lead to this outcome.

Additional actions may be taken at my discretion, including involving the Computer Science department and the university administration. Cheating also disqualifies you from any offers of help or opportunities that are available to other members of your class.

Please refer to the university policy on academic conduct: NYU Tandon Student Code of Conduct.

Policy on Collaboration

You may discuss general approaches to the homework assignments with other students. You are permitted to work with **two** other students to work out the details of the questions and write up the solutions. However, if you collaborate, you **must** list all names and netIDs at the top of the assignment.

Additionally, if you work with partners, **only one** of you should submit the assignment on Gradescope, but all members of the group are responsible for ensuring that the submission is made. If your name is not on the assignment, you will not receive any points for that submission.

It is crucial that you fully understand the work you submit. The submission must be your (and your partners') original work. Any evidence of copying (from other students, past solutions, the Internet, or third-party services) will be treated as academic dishonesty. This will result in a 0 for the assignment, a report to the department and the Dean of Student Affairs, and potentially an F in the course. For more information, see NYU CIS Policies.

Approximate Schedule

Please check for updates throughout the semester. Lecture slides will be posted on NYU Brightspace a day or two after each lecture. Last semester's slides are already available on NYU Brightspace.

The precise order and content of the course, especially in the later parts, may change. We will follow the list of topics outlined in the syllabus. The prerequisites for this course are assumed. Some topics that have been useful for students to review before a lecture are mentioned under the *Assumed Background*. This is not an exhaustive list, but if a topic appears under assumed background, I will expect you to know it for the rest of the semester. The listed resources are intended for a quick review; please consult additional materials if needed.

- **Week 1:** Introduction: What's an algorithm? Why do we want to study algorithms? Termination. Correctness. Performance. How to measure the 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. CLRS covers this material very well.

  Resources: CLRS chapters 1, & 2. See also `https://www.win.tue.nl/~kbuchin/teaching/JBP030/notebooks/loop-invariants.html` Review of asymptotic notation is in CLRS chapter 3 and `https://www.cs.cornell.edu/courses/cs312/2004fa/lectures/lecture16.htm`. Induction chapter 3 in `https://www.cs.toronto.edu/~shaharry/csc236/resources/165.pdf`

- **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, and 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, the 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. Chapters 4, 7, 9, and 33.4.

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

  Resources: CLRS chapter 4

  Please note that 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 are 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.

NYU is committed to creating an inclusive and equitable environment for all students. In this class, I aim to cultivate a strong sense of community, emphasizing that it is a space where individuals of diverse backgrounds—spanning beliefs, ethnicities, national origins, gender identities, sexual orientations, religious and political affiliations, and abilities—are treated with respect. All members of the class are expected to contribute to an inclusive atmosphere for each other. While disagreement and differing ideas are welcome, the expectation is that we respect perspectives beyond our own, even when they diverge from our personal beliefs or experiences. If you encounter disrespect or discrimination in the class or feel that the outlined standards are not being upheld, please report your experiences to me.

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://engineering.nyu.edu/student-life/student-activities/office-student-affairs/policies/code-conduct`

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