



INFO 6205: Program Structures and Algorithms

Course Information

Course Title: Program Structure and Algorithms

Course Number: INFO 6205

Term and Year: Fall 2024

Credit Hour: 4

CRN: 16346 (08) and 21593 (14)

Course Format: Classroom

Instructor Information

Full Name: Robin Hillyard

Email Address: r.hillyard@neu.edu

Office Hours: Tuesday 2pm—6pm; Friday all day (online/Teams only)

Instructor Biography

Associate Teaching Professor Robin Hillyard has taught at Northeastern University since 2015. Before that, he enjoyed a long and successful career in software development and consulting. He has served in every capacity from Chairman/President on down—in startups and more established companies—and in many industries: financial, healthcare, eCommerce, and computer-aided design. Throughout this time he was an innovator, especially in the areas of unit testing and agile development. He wrote his first program in 1968—which actually worked first time. His undergraduate degree was in Engineering Science at the University of Oxford (first class honours) with a specialty in control engineering. Switching to the “other” place, he received his Ph.D. in Computer Science in 1978 from the University of Cambridge, with a dissertation on dimensions and tolerances in computer-aided design. Always fascinated by the expressiveness of computer languages for solving problems, Dr. Hillyard has become proficient in a wide range of languages from assembly language, BCPL, Algol68, Fortran, C, Perl, Java, to Scala and many others. A long-time proponent of unit testing, he wrote his first unit test suite (for assembly language) in 1972. Having developed perhaps the world’s first object-relational database, he has previously taught relational databases at the Khoury College of Computer Sciences. He has a patent concerning the use of reactive programming for healthcare information systems. Most recently, he has been involved with “big data” on a Hadoop platform using Spark, GraphX, Scala, Elastic Search and Zeppelin for the recognition of gaps in (health) care. Research interests include: Genetic Algorithms, a blockchain-based system for public and private documents, where such documents can cite other public documents—a defense against “fake news” and revisionist history.

Teaching Assistant Information

Full Name: See Canvas

Email Address: See Canvas

Office Hours: See Canvas

Course Prerequisites

Java

Course Description

Introduction to Algorithms and Data Structures with emphasis on *why* things work.

Course Learning Outcomes

- 1) Students will be able to explain fundamental abstract data types including identifying their data structures, algorithms, and invariants.
- 2) Students will be able to predict the complexity of problems and their solutions based on theoretical considerations and will know how to validate said complexity via benchmarking and other tools.
- 3) Students will understand the primary forms of reduction: defeat-in-detail, divide-and-conquer, dynamic programming.
- 4) Students will have a thorough knowledge of sorting and searching techniques as well as graphs.

Required Tools and Course Textbooks.

ISBN 979-8-8233-5346-5 Data Structures, Algorithms, and Invariants (Preliminary Edition) by Robin Hillyard (published by Cognella).

Course Schedule/Topics Covered.

Chapter 1: Solving Problems

- Solving problems
 - Search Problems
 - Reduction
 - Modeling the Problem
 - Divide-and-Conquer & Defeat-in-Detail
 - The Master Theorem
 - P & NP
 - Invariants
 - The Arbitrary Substitution Principle
- Representing state
 - Modeling the Solution to a Problem
 - Abstract Data Types
 - Data structure, invariant, algorithm
 - Variables and collections
- Degrees of freedom and constraints
- An Important Reduction
 - The Dictionary Principle: Binary search

Chapter 2: Complexity: what is an ADT's cost in terms of resources?

- Resources: Space and Time
 - Benchmarking
- Growth of Resource Usage
 - Search problems
 - Sorting as a search problem
 - Logarithms
 - The Dictionary Principle

- Rocket Science
 - Entropy
 - Asymptotic Bounds
 - Big Omega, Big O, tilde
 - Amortized cost
 - Multivariate complexity
- 3SUM case study
 - Quadrithmic Solution
 - Quadratic (calipers) Solution

Chapter 3: What are Abstract Data Types and why do we need them?

- Representing State
 - Data Types
 - Composite Data Types
- Abstract Data Types
 - Invariants
 - Data structures
 - Arrays and Lists
 - Arrays
 - Lists
 - Application Programming Interface
 - Applications
 - API
 - Benefits of ADTs
 - Classification of ADTs
 - Order
 - Mutability
- Conclusion

Chapter 4: Unordered ADTs

- Object
- Set
- Bag
- The Filing System Principle: Classification
 - Classifiers
- Hash Table
 - Hashing
 - Buckets (Separate Chaining)
 - Open Addressing (Linear Probing)
 - The Hash Function
 - The Birthday Paradox
 - The Coupon Collector
 - Buckets vs. Open Addressing
 - Summary

Chapter 5: Positional ADTs

- Strict vs. Non-strict
- Iterator
- Array
- Lists

- Linked Lists
 - Immutable List
 - ArrayList
 - Stack
 - Relaxing Constraints
 - Lazy List
- Queues
 - Double-ended Queue
 - Circular Queue
- String

Chapter 6: Ordered ADTs

- Introduction
- Ordered Array
 - Application Programming Interface
 - Lazy Ordered Array
 - The Dictionary Principle
- Priority Queue
 - Binary Heap
 - Implementation
 - Insertion
 - Removal
 - Binary Search and Half-swaps
 - Analysis
 - Summary
- Binary Search Tree
 - Search and Insertion
 - Deletion
 - Hibbard Deletion
- Balanced Search Tree
 - Flexibility
 - Red-Black Tree
 - The “Rules”
 - Transitions
 - B-Tree
 - 2-3 Tree

Chapter 7: Sorting Part 1: Creating Order out of Comparison

- Creating Order out of Comparison
 - Sorting
 - Order
 - Comparison—Total Order
 - Keys
 - Comparison in Java
 - Counting Sorts
- Comparisons sorts
 - Adaptive Sorts
 - Bubble Sort
 - Swaps
 - Insertion Sort
 - Stable Sorting
 - Non-Adaptive Sorts
 - Selection Sort

- Optimal Sorting
 - Merge Sort
 - Quicksort
 - Merge Sort vs. Quicksort
 - Timsort
 - Heapsort
 - Shellsort
- Conclusion

Chapter 8: Order Part 2

- Sorting by Counting
 - Classification
 - Bucket sort
 - Analysis
 - Counting sorts
 - LSD Radix Sort
 - MSD Radix Sort
- Hybrid Sorts
 - Husky Sort
- Selection
 - Quickselect
- Shuffling
- Conclusion

Chapter 9: Graphs: the ultimate abstract data type

- Graph: the Ultimate Abstract Data Type
- Definitions
 - Graph
 - Disjoint Sets (Edgeless Graphs)
 - Edge-based Graphs
 - Types of Edge
 - Directed vs. Undirected Graph
 - Directed Acyclic Graphs (DAG)
 - Tree
 - Directed Tree
 - Undirected Tree
 - Spanning Tree
- Graph Representations
 - Model E
 - Model V
 - Model A
- Graph Complexity
- Graph Applications
 - Depth-first search
 - Breadth-first search
 - Connectivity
 - Ordering
 - Strong Connectivity
 - Minimum Spanning Tree
 - Kruskal's Algorithm
 - Prim's Algorithm
 - Shortest Paths
 - Dijkstra's Algorithm

- Acyclic Algorithm
 - Bellman-Ford Algorithm
 - Interesting Graph Problems
 - The Seven Bridges of Königsberg
 - Hamilton Cycle
 - Subgraph Isomorphism
- Conclusion

Chapter 10: Other Graph Topics

- Part 1: Union-Find (Disjoint Sets)
 - The Best Case
 - Eager Solution
 - Lazy Solution
 - An Optimal Solution?
 - Summary
- Part 2: Dynamic Programming
 - Introduction
 - Dynamic Programming
 - Reduction by Directed Graph
 - Reduction by Directed Acyclic Graph
 - Reduction by Directed Cyclic Graph
 - Applying the Dynamic Programming Method
 - Fibonacci
 - Knapsack Problem

Week	Date	In Class Topic	Assignment Due
1	09/04	To be determined	TBD
2	09/11	To be determined	TBD
3	09/18	To be determined	TBD
4	09/25	To be determined	TBD
5	10/2	To be determined	TBD
6	10/9	To be determined	TBD
7	10/16	To be determined	TBD
8	10/23	To be determined	TBD
9	10/30	To be determined	TBD
10	11/6	To be determined	TBD
11	11/13	To be determined	TBD
12	11/20	To be determined	TBD
13	11/27	To be determined	TBD
14	12/4	To be determined	TBD
15	12/11	To be determined	TBD
16	12/18	To be determined	TBD

Grading

- Attendance – 4 %
- Assignments – 17%
- Quizzes – 18%
- Team Project – 22 %

- Midterm Exam – 17%
- Final Exam – 22%

Grading Scale

There is no fixed scale for determining final grades. As a rough guide, 95% or above will generally earn an A. 80% or more should get you a B-. But I repeat: there is no fixed scale for grading.

Attendance/Late Work Policy

Attendance Policy

Students registered in MGEN courses (INFO, CSYE, and DAMG) are allowed **a maximum of 2 absences per course, with 3 or more absences resulting in an automatic 'F' for that course.** Students are expected to inform their instructors of any absences in advance of the class; if a student is sick long-term or experiences a medical issue that prevents class attendance, it is strongly encouraged that they speak with their Academic Advisor (coe-mgen-gradadvising@northeastern.edu) to learn more about the Medical Leave of Absence. Should a student anticipate being unable to attend 3 or more classes, they should discuss their situation with their Academic Advisor to explore other types of leave in accordance with the University's academic and global entry expectations. International students should review the Office of Global Services webpage to understand their visa compliance requirements.

Teaching Assistants (TAs) or Instructional Assistants (IAs) will be present at each class to collect student attendance.

Late Work Policy

Students must submit assignments by the deadline in the time zone noted in the syllabus. Students must communicate with the faculty prior to the deadline if they anticipate work will be submitted late. Work submitted late without prior communication with faculty will not be graded.

End-of-Course Evaluation Surveys

Your feedback regarding your educational experience in this class is particularly important to the College of Engineering. Your comments will make a difference in the future planning and presentation of our curriculum.

At the end of this course, please take the time to complete the evaluation survey at <https://neu.evaluationkit.com>. Your survey responses are **completely anonymous and confidential**. For courses 6 weeks in length or shorter, surveys will be open one week prior to the end of the courses; for courses greater than 6 weeks in length, surveys will be open for two weeks. An email will be sent to your Northeastern University Mail account notifying you when surveys are available.

Academic Integrity

A commitment to the principles of academic integrity is essential to the mission of Northeastern University. The promotion of independent and original scholarship ensures that students derive the most from their educational experience and their pursuit of knowledge. Academic dishonesty violates the most fundamental values of an intellectual community and undermines the achievements of the entire University.

As members of the academic community, students must become familiar with their rights and responsibilities. In each course, they are responsible for knowing the requirements and restrictions regarding research and writing, examinations of whatever kind, collaborative work, the use of study aids, the appropriateness of assistance, and other issues. Students are responsible for learning the conventions of documentation and acknowledgment of sources in their fields. Northeastern University expects students to complete all examinations, tests, papers, creative projects, and assignments of any kind according to the highest ethical standards, as set forth either explicitly or implicitly in this Code or by the direction of instructors.

Go to <http://www.northeastern.edu/osccr/academic-integrity-policy/> to access the full academic integrity policy.

MGEN Student Feedback

Students who would like to provide the MGEN unit with anonymous feedback on this particular course, Teaching Assistants, Instructional Assistants, professors, or to provide general feedback regarding their program, may do so using this survey: https://neu.co1.qualtrics.com/jfe/form/SV_cTIAbH7ZRaaw0Ki

University Health and Counseling Services

As a student enrolled in this course, you are fully responsible for assignments, work, and course materials as outlined in this syllabus and in the classroom. Over the course of the semester if you experience any health issues, please contact UHCS.

For more information, visit <https://www.northeastern.edu/uahcs>.

Student Accommodations

Northeastern University and the Disability Resource Center (DRC) are committed to providing disability services that enable students who qualify under Section 504 of the Rehabilitation Act and the Americans with Disabilities Act Amendments Act (ADAAA) to participate fully in the activities of the university. To receive accommodations through the DRC, students must provide appropriate documentation that demonstrates a current substantially limiting disability.

For more information, visit <https://drc.sites.northeastern.edu>.

Library Services

The Northeastern University Library is at the hub of campus intellectual life. Resources include over 900,000 print volumes, 206,500 e-books, and 70,225 electronic journals.

For more information and for education specific resources, visit <https://library.northeastern.edu>
Network Campus Library Services: [Northeastern University Library Global Campus Portals](#)

24/7 Canvas Technical Help

For immediate technical support for Canvas, call 617-373-4357 or email help@northeastern.edu

Canvas Student Resources: <https://canvas.northeastern.edu/student-resources/>

For assistance with my Northeastern e-mail, and basic technical support:
Visit ITS at <https://its.northeastern.edu>
Email: help@northeastern.edu
ITS Customer Service Desk: 617-373-4357

Diversity and Inclusion

Northeastern University is committed to equal opportunity, affirmative action, diversity, and social justice while building a climate of inclusion on and beyond campus. In the classroom, members of the University community work to cultivate an inclusive environment that denounces discrimination through innovation, collaboration, and an awareness of global perspectives on social justice.

Please visit <http://www.northeastern.edu/oidi/> for complete information on Diversity and Inclusion

Title IX

Title IX of the Education Amendments of 1972 protects individuals from sex or gender-based discrimination, including discrimination based on gender-identity, in educational programs and activities that receive federal financial assistance.

Northeastern's Title IX Policy prohibits Prohibited Offenses, which are defined as sexual harassment, sexual assault, relationship or domestic violence, and stalking. The Title IX Policy applies to the entire community, including male, female, transgender students, faculty, and staff.

In case of an emergency, please call 911.

Please visit <https://www.northeastern.edu/ouec> for a complete list of reporting options and resources both on- and off-campus.