CSCI 104
Overview

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Updated for Fall 2022 by Andrew Goodney

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Administrivia 1

- In-Person
  - One lecture section will be recorded, however the recordings will not be posted on lecture day. Rather the recordings will be posted in tranches before the exam and final.
- CS 103 / 170 Preparation
  - Basic if, while, for constructs
  - Arrays, linked-lists
  - Structs, classes (constructors, destructors, operator overloading, copy semantics, inheritance)
  - **Dynamic memory allocation and pointers**
  - Recursion
  - Asymptotic Notation: Big-O/Theta/Omega notations
- All other content is on our website (https://bytes.usc.edu/cs104/)

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Administrivia 2

- Syllabus
  - https://bytes.usc.edu/cs104/syllabus/
  - Exams: 1 midterm and 1 final
  - Six assignments.
    - Each assignment has a written component and a programming component
    - Key: **Start early, work consistently,** and meet the "checkpoint" schedule.
- Expectations
  - Class should be interactive. Speak up directly (I don't mind being interrupted) or raise your hand.
  - I'll give you my best, you give me yours…
    - Attendance, participation, asking questions, academic integrity, take an interest
  - Treat CS104 right!
  - Let's make this fun

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Organizing Your Data

- Intentionally vague question: *"Should you always **sort** your data?"*
  - No. What are the tradeoffs?
  - An **Insert** operation becomes more expensive, but a **Lookup** operation becomes less expensive
  - In a backup system, you are constantly inserting information, and you rarely (hopefully never) performing lookups on that information.
- How should you organize your data? What is the best data structure?
  - The answer is, invariably, "it depends."
  - Otherwise, this class would be called "Data Structure" (singular), I'd teach it to you today, and everyone would go home and get an A.
  - Demo…Need 2 volunteers

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Data Structure Consideration

- **Some questions to consider:**
  - Will you search the data often?
  - Will data be added in small, frequent chunks?
  - Will data be added in large, infrequent chunks?
- Besides Insert and Lookup, what other operations are common?
  - **Remove** and **Update**
- Which of these operations you need, and how frequently you need each one, will dictate which data structure you select!
  - There is a data structure called a "Heap" which is really good at all of these operations… except Lookup!
  - Others, such as AVL Trees, are able to do all 4 operations fairly well (but they are worse than Heaps on every operation except Lookup!)
  - Yet others, such as Hash Tables, are usually lightning fast, but are probabilistic and occasionally produce very bad runtimes.

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Why Data Structures Matter?

- Modern applications process vast amount of data
- Adding, removing, searching, and accessing are common operations
- Various data structures allow these operations to be completed with different time and storage requirements

Data Structure	Insert	Lookup	Get-Min
Unsorted List	$\Theta(1)$	$\Theta(n)$	$\Theta(n)$
AVL Tree	$\Theta(\log n)$	$\Theta(\log n)$	$\Theta(\log n)$
Heap	$\Theta(\log n)$	$\Theta(n)$	$\Theta(1)$

Recall Θ (n) indicates that the actual run-time is bounded by some expression $a*n$ for some $n > n_0$ (where a and n_0 are constants)

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Why Data Structures Matter?

- As engineers we get to design/implement solutions by asking questions
- Should we keep our data in an unsorted list, or put it in an AVL tree?

Data Structure	Insert	Lookup	Get-Min
Unsorted List	$\Theta(1)$	$\Theta(n)$	$\Theta(n)$
AVL Tree	$\Theta(\log n)$	$\Theta(\log n)$	$\Theta(\log n)$
Heap	$\Theta(\log n)$	$\Theta(n)$	$\Theta(1)$

- n items, m look ups?
- Under what conditions do we:
  - Leave the data unsorted?
  - Put it into an AVL tree?

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Why Data Structures Matter?

- Unsorted list:
  - n items, m lookups = n*m
- AVL tree:
  - n items, with $\Theta(\log n)$ insert = $\Theta(n * \log n)$
  - m lookups: $\Theta(m * \log n)$
  - Total = $\Theta(n * \log n) + \Theta(m * \log n) = \Theta((n+m) * \log n)$
- Now we can answer the design question
  - Unsorted $n*m < (n+m) * \log n$
  - AVL otherwise
- Put in some reasonable estimates for n and m… or if $n \approx m$ then we get
  - n^2 vs $n \log n$
- What does n^2 vs $n \log n$ look like?

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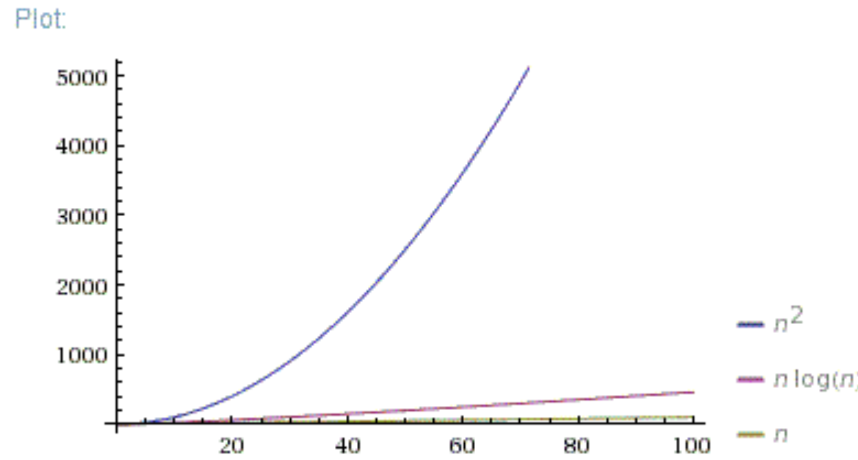
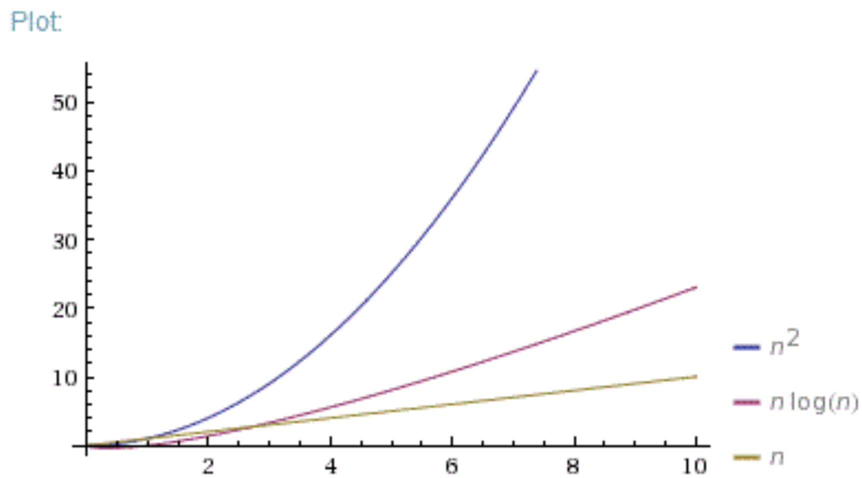
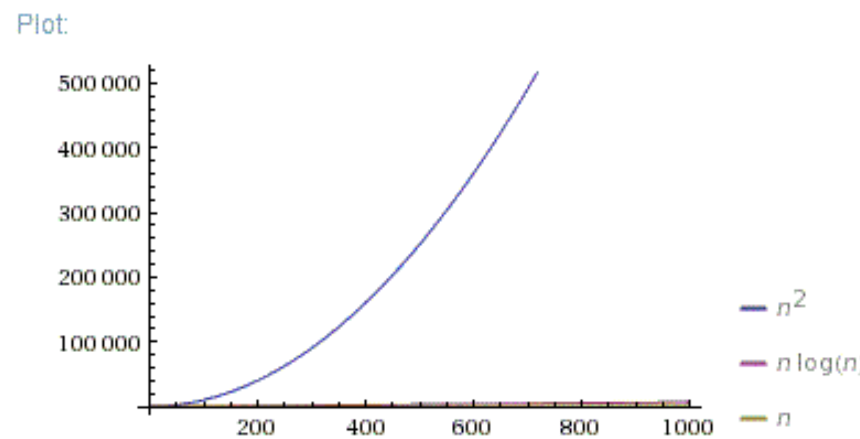
Why Data Structures Matter?

- $\Theta(n^2)$ vs $\Theta(n \log n)$
- 0 -> 10
- 0 -> 100
- 0 -> 1000







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Importance of Complexity

Problem Size	Estimated run time					
n =	log n	n	n log n	n^2	2^n	n!
10	3×10^{-11} s	10^{-10} s	3×10^{-10} s	10^{-9} s	10^{-8} s	3×10^{-7} s
10^2	7×10^{-11} s	10^{-9} s	7×10^{-9} s	10^{-7} s	4×10^{11} yrs	*
10^3	10^{-10} s	10^{-8} s	10^{-7} s	10^{-5} s	*	*
10^4	1.3×10^{-10} s	10^{-7} s	10^{-6} s	10^{-3} s	*	*
10^5	1.7×10^{-10} s	10^{-6} s	2×10^{-5} s	0.1 s	*	*
10^6	2×10^{-10} s	10^{-5} s	2×10^{-4} s	10.2 s	*	*

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Abstract Data Types

- Programming students tend to focus on the code and less on the data and its organization
- More seasoned programmers focus first on
  - What data they have
  - How it will be accessed
  - How it should be organized
- An **abstract data type** describes what data is stored and what operations are to be performed
- A **data structure** is a specific way of storing the data implementing the operations
- Example **ADT**: <u>List</u>
  - Data: items of the same type in a particular order
  - Operations: insert, remove, get item at location, set item at location, find
- Example **data structures** implementing a <u>List</u>: Linked List, array, etc.

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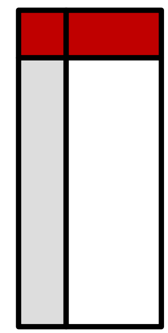
Another ADT

- `add(key, value)`
  - The key is a unique identified that we can use to find the value in the future.
  - `add("Tetris", 3)`
- `lookup(key)`
  - `Lookup("Tetris")`, to find `"Tetris"` sales rank
- `remove(key)`
  - `remove("Tetris")`, to remove "Tetris".
- This ADT is known as a **map**. We could implement the above map using a sorted list. So, is a sorted list an ADT?
  - No! The sorted list is the data structure. The map is the ADT.



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Course Goals

01

Learn basic and advanced techniques for implementing data structures and analyzing their efficiency

- Will require mathematical analysis from CS 170

02

Learn how to identify the best data structure for your needs.

03

Learn object-oriented design principles that make your code readable, modular, and extensible

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