CS 162
Intro to Computer Science II

Lecture 24

Linked List

Assignment 4 Help

Final remarks

3/15/24

Oregon State University

Odds and Ends

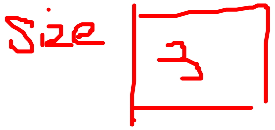
- Due reminder:
  - Quiz 5 due Sunday midnight via Canvas – open after today's lecture
  - Assignment 4 due Sunday midnight via TEACH
    - Grace days are allowed

- Today is the last day to demo:
  - Assignment 3 without late demo penalty
  - Assignment 1&2 with 30% late demo penalty

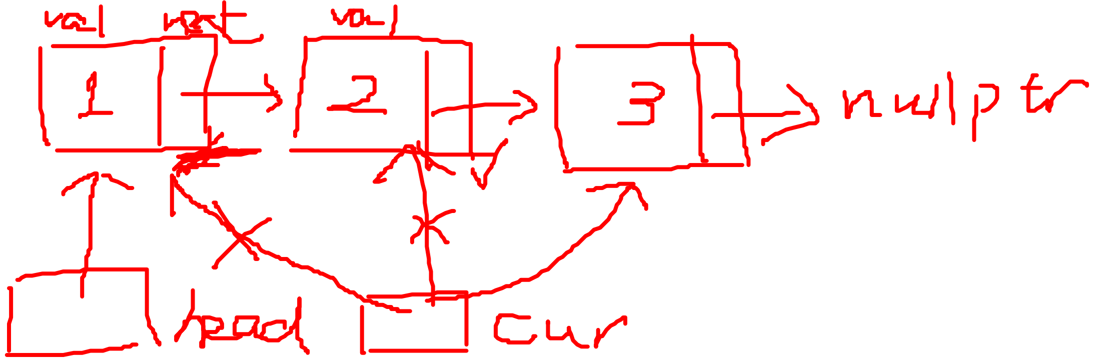
- Final Exam:
  - Wednesday 3/20 at 12pm at LINC 200

Today’s topic(s)

- Linked list
- Final exam review



In class activity



- Use the code provided on Canvas, complete the following tasks:
  - Task 1: What does the code do? (Hint: Trace through the code by drawing the picture out)
  - Task 2: Write code to print the list you just created. Trace the code you wrote to verify
    - Hint: Use while loop and Node* current
  - Task 3: Delete the list you just created. Trace the code you wrote to verify
    - Hint: You might need another Node*

Pros and Cons of Singly Linked List

- Pros
  - Easy to implement
  - Insertion and deletion of elements can be done easily and doesn’t requires movement of all elements compared to an array
  - Can allocate or deallocate memory easily during its execution
- Cons
  - Uses more memory when compared to an array
  - No random access
  - Traversing in reverse is not possible for singly linked list

Today's topic(s)

- Linked list
- Final exam review

Final Exam

- Weight: 15% of course grade
- Time: Wednesday 12:00 – 12:50 pm
- Where: LINC 200
- Close book, close notes, no calculator
- Scratch paper will be provided if needed
- Bring pen/pencil, and your photo ID
- Question types:
  - T/F, multiple choice
  - Similar as the midterm exam ☺
- Question amount: ~40

Coverage

- Non-cumulative
- Emphasis on material covered after Midterm (90%)
  - Lecture 14-24 (start from shallow vs. deep copy)
  - Lab 6 – 10
  - Worksheet 6-10
  - Assigned Reading
  - Assignment 3-4
- General coverage of earlier topics (10%)

Topics

- Shallow vs. Deep copy
- Big 3 and their usage
- Inheritance
- Upcasting vs. downcasting
- Polymorphism
- Virtual vs. pure virtual
- Abstract class
- Function/class templates
- Standard Template Class (STL)
    - vector
- Containers
- Linked List (singly)
- Recursion

Study Guide

- Take the practice exam and time yourself
- Lecture slides 14-24
- Quiz 3-5
- Worksheet 6-10
- Lab 6-10
- Assignment 3-5
- Assigned readings

Winter 2023 Exam Review

You have learned MANY things from CS 162

- Pointers
- Memory model
  - Stack vs. heap
- Dynamic Arrays
- Structs
- File separation
  - .h .cpp
  - Header guards
- Makefile
  - Compilation process
- File I/O
- Object Oriented Programming
  - Encapsulation
- Struct vs. Class

- C++ Classes
  - Access specifiers: private, public, protected
  - Accessor and Mutator functions
  - this keyword
  - Constructors: default vs. non-default
  - const
  - Big Three
    - Copy constructor
    - Assignment operator overload
    - Destructor
  - Class composition vs. class inheritance
  - Polymorphism

You have learned MANY things from CS 162

- Template
  - STL
- Containers
  - Linked list vs. array
  - Vector
- Recursion

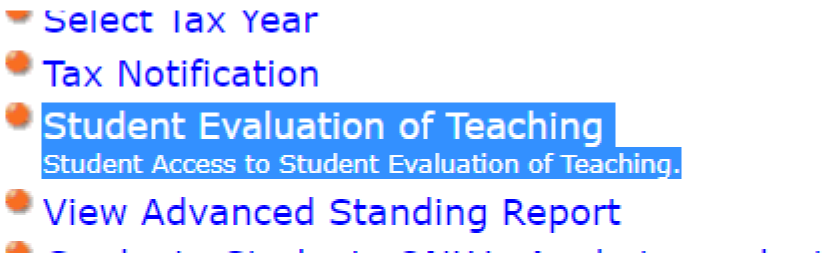
Be Confident...

Now you are able to...

- Design and implement programs that require:
  - multiple classes and structures
  - hierarchies of classes that use inheritance and polymorphism
  - an understanding of abstraction, modularity and separation of concerns
- Construct and use basic linear structures (arrays, stacks, queues, and various linked lists) in programs, and be able to describe instances appropriate for their use.
- Develop test-data sets and testing plans for programming projects.
- Produce recursive algorithms, and choose appropriately between iterative and recursive algorithms.

Final Remarks…

- Thank you so much for your commitment to this course
- What's next ?
  - CS 261: Data Structure
  - ECE/CS 271: Computer Architecture and Assembly Language
  - CS 290: Web Development
- Future improvements?
  - Canvas SLE→



- ULA position
  - Contact me! And apply through: https://jobs.oregonstate.edu/postings/140560

Final Remarks…

- Submit all your work by the deadline
  - Assignment 4, Quiz 5

- Take the Final Exam on Wednesday
  - Bring your photo ID

- Grade disputation:
  - By 3/23 6pm

Assignment 4 Q&A

*Additional topic(s)

- Complexity Analysis

*Note: this will not be in the final

How to compare/describe algorithms

- We have different data structures and sorting algorithms, how to compare them?
- We want a way to characterize runtime or memory usage that is completely **platform-independent**
  - i.e. does not depend on hardware, operating system, programming language, etc.

Complexity Analysis

- Use Complexity Analysis to help make platform-independent comparisons of data structures
  - Refer to as Big O

- Allow us to assess a data structure or algorithm's resource usage (i.e., runtime and memory consumption) in an abstract way

- To do this, we describe how a data structure's or algorithm's runtime or memory usage changes relative to a change in the input size (**n**)

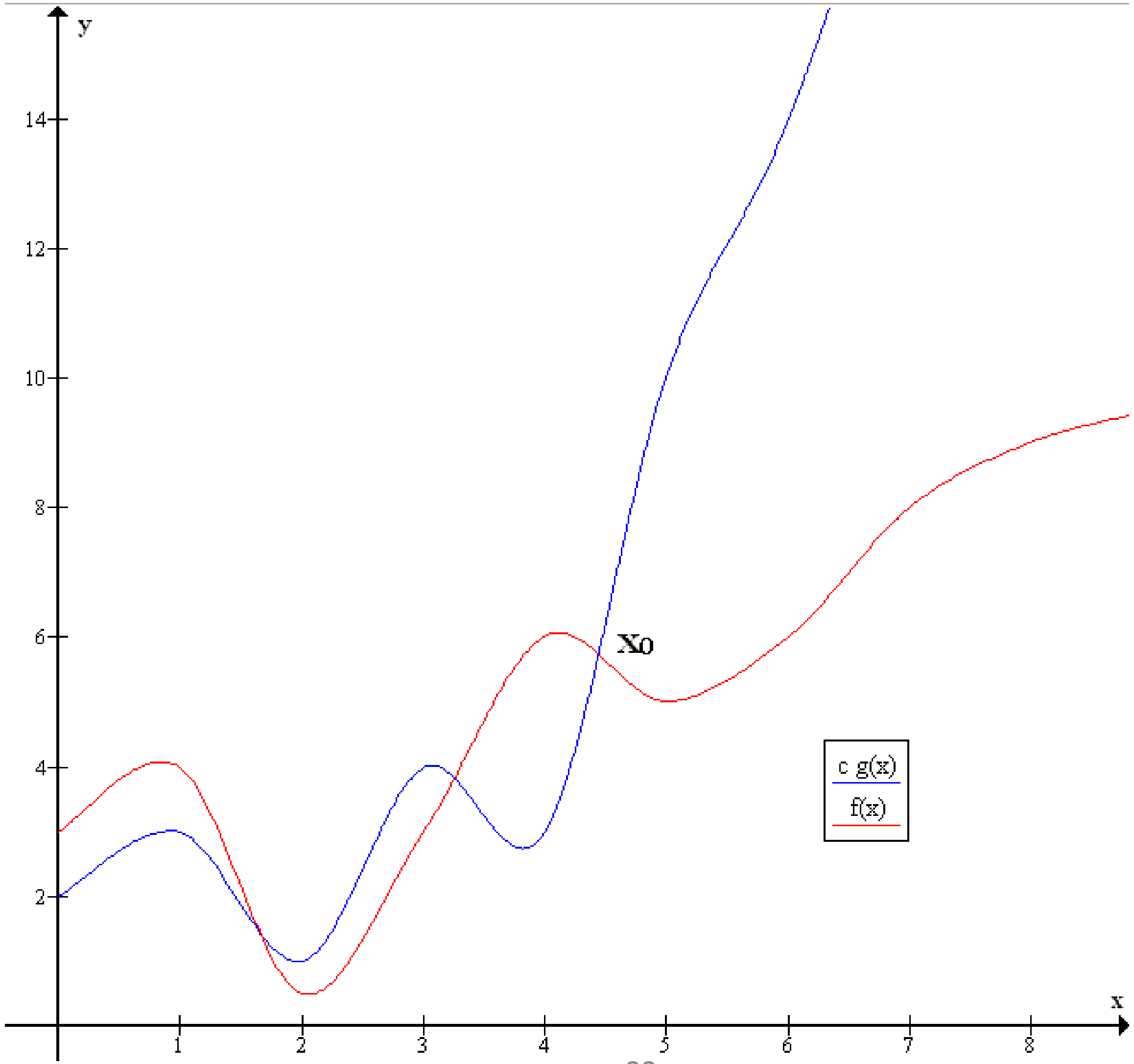
Big O

- We use Big O notation to assess a data structure or algorithm's performance.

- Big O notation: a tool for characterizing a function in terms of its growth rate
  - Indicate an upper bound on the function's growth rate, known as growth order

Big O

g(x) provides an upper bound on *f(x)*



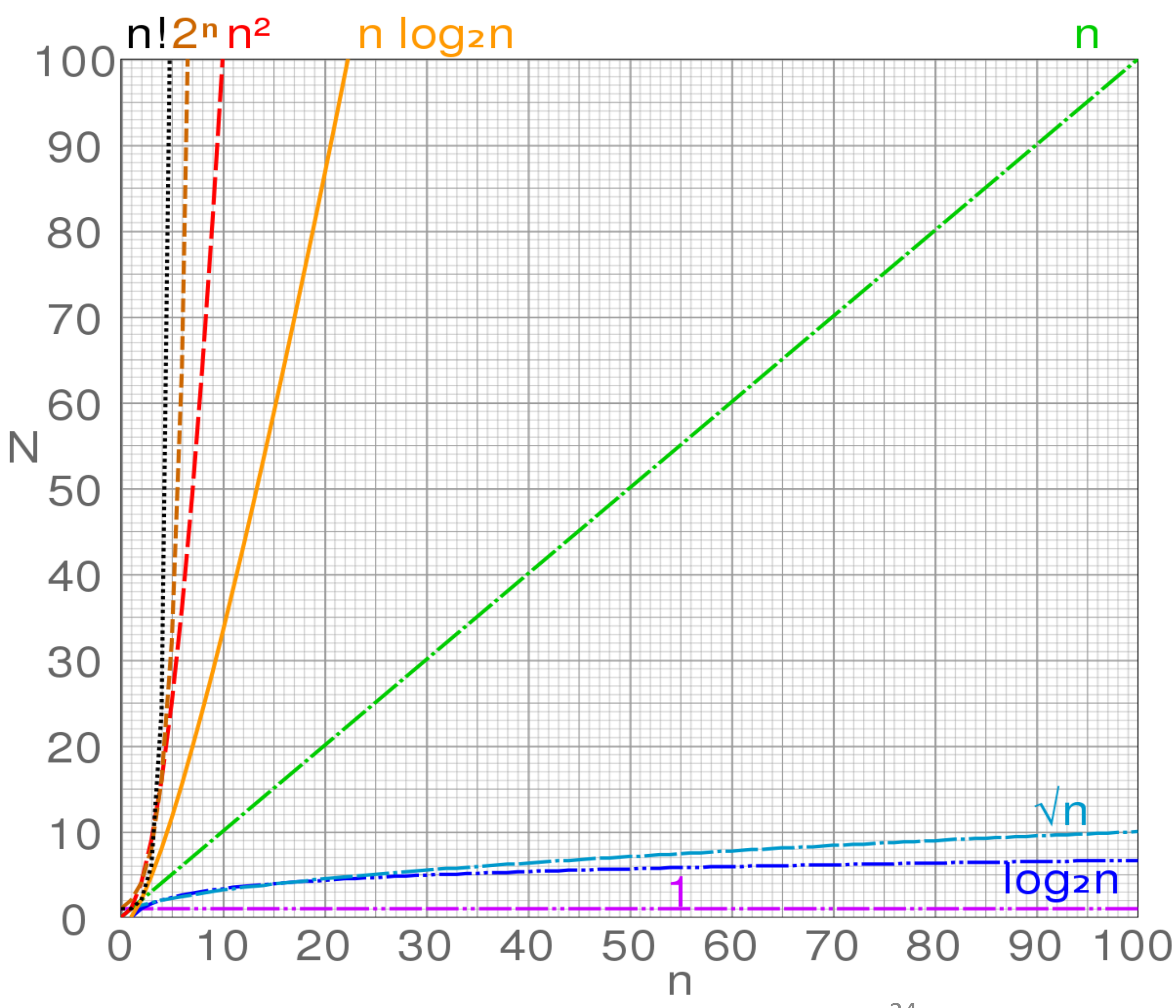
g(x) is *O(f(x))*

Big O

- To assess a data structure or algorithm's complexity, we will compute a growth order for its runtime (or memory usage) as a function of the input size n

- Importantly, we want to describe how data structures behave in the limit, as n approaches ∞ (infinity)

Common growth order functions



Common growth order functions

- O(1) – constant complexity
- O(log n) – log-n complexity
- O(√n) – root-n complexity
- O(n) – linear complexity
- O(n log n) – n-log-n complexity
- O(n^2) – quadratic complexity
- O(n^3) – cubic complexity
- O(2^n) – exponential complexity
- O(n!) – factorial complexity

Big O

- Consider this example…

```
int sum = 0;
for (i = 0; i < n; i++) {
     sum += array[i];
}
return sum;
```

- This function is summing an array of n integers
- What's the run-time complexity of the function?

Big O example

```
int sum = 0;
for (i = 0; i < n; i++) {
        sum += array[i];
}
return sum;
```

- The instruction `int sum = 0;` executes in some constant time c1 independent of n
- Each iteration of the loop executes in some constant time c2, and this happens n times
- The return statement executes in some constant time c3 independent of n
- So runtime is c1 + c2*n + c3
- c1, c2, and c3 depend on the particular computer running this function, so we ignore them to figure out run-time complexity
- Thus, this function grows on the order of n, a.k.a. its run-time complexity is **O(n)**

Determining a program’s complexity

```
node* push (node * head, int val) {
        node *temp = new node;
        temp->val =val;
        temp->next = head;
        head = temp;
        return head;
}
```

- Every instruction in this function executes in some constant time, independent of n
- Thus we ignore them to figure out runtime complexity.
- Complexity: O(c1+c2+c3+c4+c5) = **O(1)**

Dominant components

- When a growth order function has additive terms, one of those will dominate the others
  - Specifically, function *f(n)* dominates *g(n)* if n0:n>n0, *f(n)* > *g(n)*

- In these cases, we simply ignore the non-dominant terms
  - i.e. $n^2 - n$, n^2 dominates n, so we ignore n, and we say this complexity is $O(n^2)$

More examples

- Loops are one of the main determinants of a program's complexity

- ```
  for (int i = 0; i < n; i++) {
        ...
  }
  ```

- ```
  for (int i = n; i > 0; i/=2) {
        ...
  }
  ```

- ```
  for (int i = 0; i*i < n; i++) {
        ...
  }
  ```
  ```

More examples

- ```
  for (int i = 0; i < n; i++) {
        for (int j = 0; j < n; j++) {
                      ...
        }
  }
  ```

- ```
  for (int i = n; i > 0; i/=2) {
        for (int j = 0; j < n; j++) {
                      ...
        }
  }
  ```

Real-world Consideration

- Your program will only perform as well as your design
  - Constant factors can still play a part
- Suppose you have two algorithms…
  - Algorithm A) 1,000,000n → O(n)
  - Algorithm B) 2 n^2 → O(n^2)
  - Which one is better?
    - It depends