Data structures lab – week 3

Welcome back!

Wake-up quiz

- Based on your intuition (or knowledge), which of the following statements is true about Linked Lists (LL) and binary search trees (BST):

  a) LLs have faster search time than BSTs

  b) BSTs have faster search time than LLs

  c) They have the same search time

- Correct answer is c.
  - After this class, you will know why.

Outline

- Last week
- Winter warmup comments
  - Hints for future success
- Pseudo-code to implementation-code
- Trees in the forest
- Assignment 2

By the way, did you know that C++ was originally invented by a Danish guy?

Week 2 recap

- How a lab lecture works
- Linked Lists
  - Revisited today
- Coding guidelines
  - Also revisited today
- Assignment questions
  - May be revisited today
    - But hopefully, you all did assignment 1 by now.

Week 2 class evaluation

- 100% increase in responses!
  - Up from 7 to 14
- Selected comments (slightly edited)
  - ”Cover more material”
  - ”Spend more time on projects”
  - ”Eclipse is not everything”
  - ”go ducks!!!”
- Full survey results online

Hints for success

- Hint number 1: Read the assignment
- ”You should conform **exactly** to the input and output specification.”
  - ”Let me say that again: **conform exactly to the input and output specification**”
    - This is from the website.
- Many had extra stuff in there.
  - ”Please input a number”
  - ”Please input a name”

Hints for success

- Hint number 2: Look at your code

```
#include <warmup.h>
#include <iostream>
using namespace std;
int main()  {
    std::cout << "I like to do
        more than necessary";
    return 0;
}
```

Not included

std:: not necessary

- What's wrong here?

Hints for succes

- Hint number 3: Comply with standards.
  - And knowledgeable people.
- Quote from the C++ FAQ Lite:
  - ”`main()` must return `int`. Not `void`, not `bool`, not `float`. `int`. Just `int`, nothing but `int`, only `int`.”
- With g++, ”`void main()`” will not compile, ”`main()`” will.
  - But that does not make it correct

Hints for success

- Hint number 4: Use large test cases

  `char[400][100]`

  - Stores 400 names of length 100
  - What's wrong with that?
- It is easier to catch errors like the above.
- It is easier to get a feel for running time.

Hints for success + prosperity

- Hint number 5: Use the terminal.
- Easier for testing large test cases
  - ./myProgram < largeTestCase > outputTestcase
- Eclipse can still be used as development environment, if you prefer.
- The terminal is powerful beyond C++!

Wake-up quiz – hints for success

- What was hint number 1?
  - a) Use the terminal
  - b) Use large test cases
  - c) Comply with standards
  - d) Look at your code
  - e) Read the assignment
- e is correct but they are all important!

From pseudo to implementation

- Find an algorithm in pseudocode
- (Understand the algorithm)
- Implement the algorithm
- Wait, how do we do this again?
  - I don't know what pseudocode is
  - I don't know where to find the pseudocode
  - What about data structures?
- Well, listen closely

A pseudo stack

- I want to implement a stack and the elementary stack operations
- I look at chapter 10 in Cormen
  - This is where the pseudocode is.
- I see something that has line numbers and a different font than everything else
  - This is the pseudocode.

A pseudo stack

- Now, I have the pseudocode for
  - StackEmpty(*S*), checks if *S* is empty
  - Push(*S*,*x*), add element *x* on to *S*
  - Pop(*S*), remove the top element from *S*
- But what is S?
  - It depends on the situation.
  - It depends on what I need.
  - But I need to know at least the *top* element

A stack implementation

```
struct element {
  string name;
  element * below_me;
};

struct stack {
  element * top;
};
```

A stack implementation

```
bool stackEmpty(stack& S) {
   if (S.top == NULL)
      return true;
   return false;
}

void push(stack& S, element& x) {
   x.below_me = S.top;
   S.top = &x;
}

element * pop(stack& S) {
   element * x;
   x = S.top;
   S.top = x->below_me;
   return x;
}
```

Wake-up quiz – stack 'em up

- A Linked List can represent both stacks and queues. Can stacks by themselves be used to represent a queue?

  a) yes, we need one stack to do it.

  b) yes, we need two stacks to do it.

  c) yes, we need three stacks to do it.

  d) no

- Correct answer is b.

A queue – stack style

- I want to implement a queue using two stacks.
- I already have a stack data structure.
- I need the pseudocode for the queue operations.
  - I don't have this.
    - Yay, I get to solve a problem.

A queue – stack style

- EnQueue(*Q*,*x*)
  - Just push *x* onto *head.*
- DeQueue(*Q*)
  - If *tail* is empty
    - Loop until *head* is empty
      - Pop element *x* form *head*
      - Push element *x* to *tail*
  - Return Pop of *tail*

A queue – stack style

- How does the data structure look?

```
struct queue {
    stack head;
    stack tail;
};
```

A queue – stack style

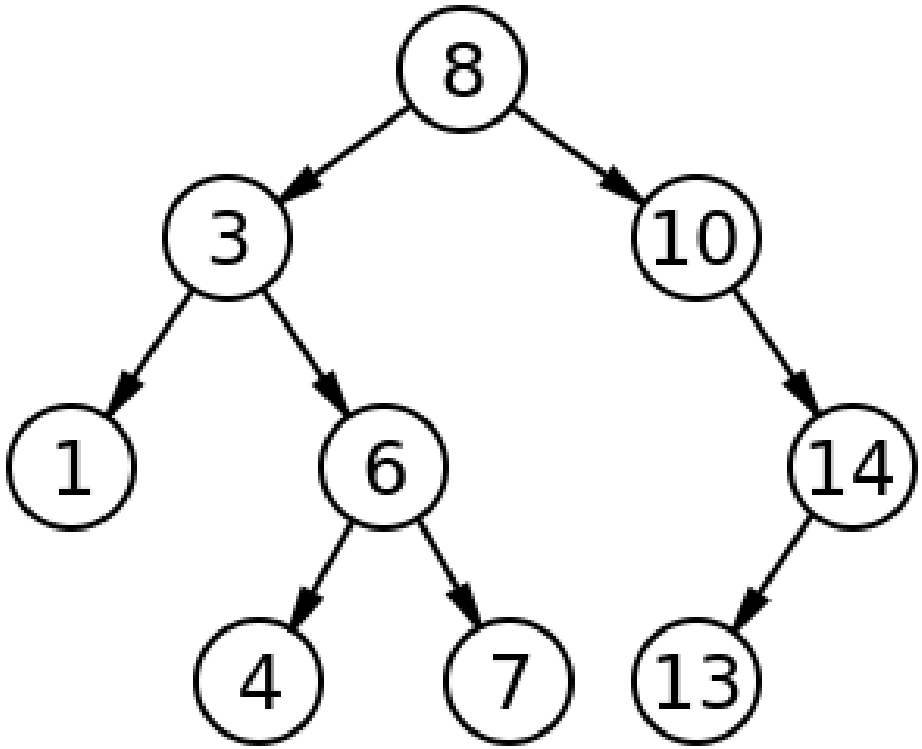
```
void enQueue(queue& Q, element& x) {
   push(Q.head,x);
}

element * deQueue(queue& Q) {
   if (stackEmpty(Q.tail)) {
      while (!stackEmpty(Q.head)) {
         element * x;
         x = pop(Q.head);
         push(Q.tail,*x);
      }
   }
   return pop(Q.tail);
}
```

From pseudo to implementation

- Look in the book
- Identify the important features of a data structure or choose existing one
- Try to map the pseudocode to the programming language
  - Pseudocode does not know the difference between a pointer and a reference
    - (Do you?)

Trees in the forest



This is a binary search tree

Binary search trees

- Every node has at most 2 children.
- Every node consists of:
  - A *key*
  - A pointer to the left child, *left*
  - A pointer to the right child, *right*
  - A pointer to the parent, *p*

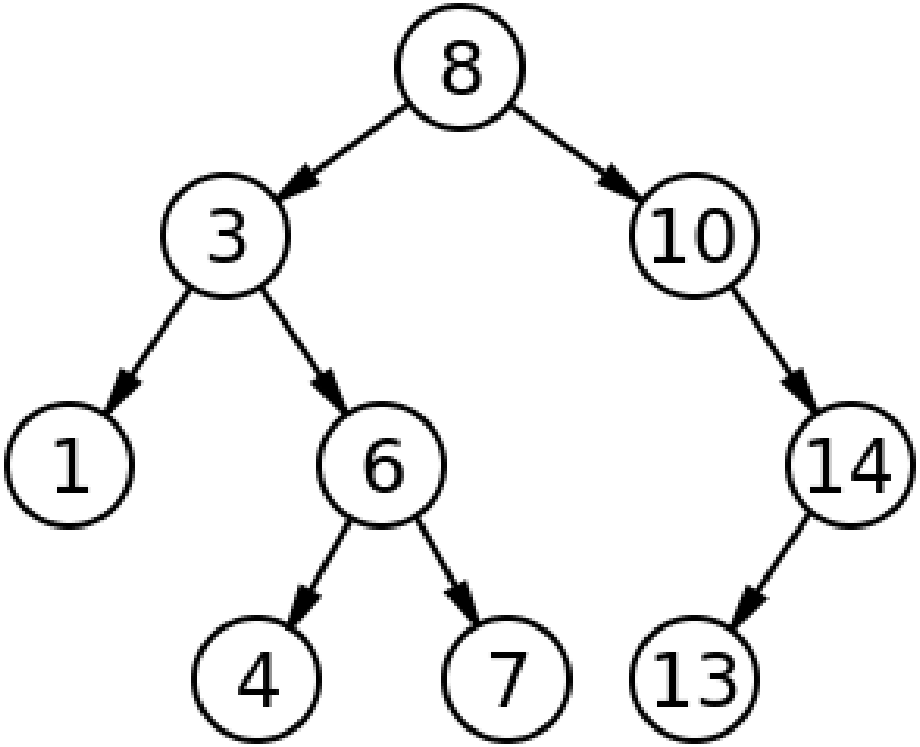
Binary search trees

- Every node *x* satisfies the ***binary-search-tree-property (bstp):***
  - For every node *y* in the left subtree of *x*:
    - *y.key* <= *x.key*
  - For every node *y* in the right subtree of *x*:
    - *y.key* >= *x.key*

Binary search tree

- Often used for search
- Because of the bstp, searching for a value *k* is pretty straightforward
  - Start at the root *r*
  - If *k* < *r.key*
    - Go left
  - Else
    - Go right
- Insertion is similar

Tree Search



Wake-up quiz – BSTs

- A BST *T* has *n* nodes and height *h*
- What is the running time of tree-search?

  a) O(lg n)

  b) O(h)

  c) O(n)

  d) O(n^2)

- Correct answer is b
  - For a complete binary tree, $h = \lg n$

Assignment 2

- Implement a binary search tree data structure.
  - Support insert and search
  - Do not bother about deletion
- Expand your linked list from A1 to include searching
- Compare running time for search with BST and LL.

Assignment 2

- Back to the first warm-up question
- What happens if the BST is just one big line of nodes?
  - LL and BST running time is the same!
  - O(n)
  - How can we deal with this?

Assignment 2

- We want the BST to have height lg*n*
- We can balance the tree
  - coming up later in the term
- We can randomize the insertion
  - You will do this in the assignment.
  - Hopefully, this will lead to a performance boost.
    - The book says it does.
    - You should measure it.

Programming help

- H.E.L.P. = Help Enhances the Learning Process.
- Every Monday, 5pm-6pm
- Deschutes 100.
- Things you should do:
  - Read the assignment beforehand
  - Have specific questions
  - Try on your own before asking

Grades

- You have each been assigned a ”secret” number, avoiding the use of student ids.
- As an extra bonus, you will have to figure out the secret number yourself. Here's how:
  - Create a C++ program and:
    - Use your student id as the ”seed” for the standard random number generator
    - Read the random number
- Grades will be posted later today

Thank you

Questions?