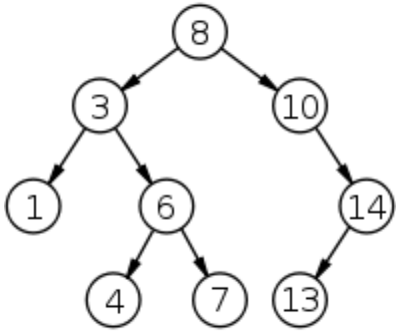


Q1

CSSE 230 Day 7

More BinaryTree methods
Tree Traversals
Exam review

After today, you should be able to…
… traverse trees on paper & in code

Announcements

- Doublets is next assignment.
- Also with a partner – meet during break.
- Instructor demo

Announcements

- Please complete the Stacks&Queues partner evaluation in Moodle after you submit your final code.

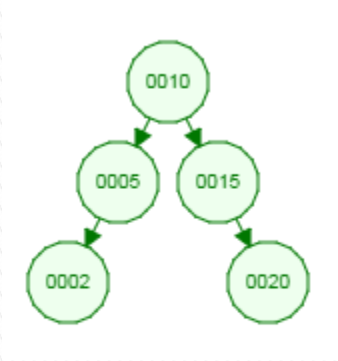
- Optional Exam 1 review session:
  - Sunday 9/17 from 8-11pm, Percopo classroom, led by CSSE230 tutor Connor Boyle

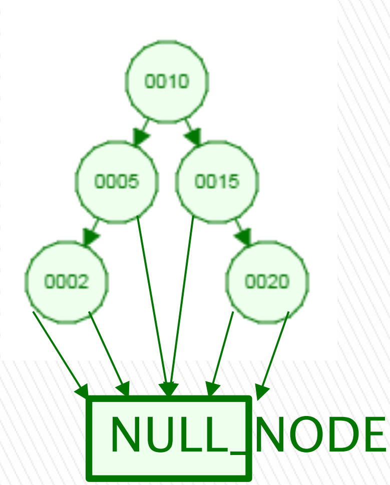
Questions?

Quiz question: What became clear to you as a result of class?

CSSE230 student: I was **tree**ted to some good knowledge by the time I **leaf**t.

A dummy NULL_NODE lets you recurse to a simpler base case while avoiding null pointer exceptions





4 possibilities for children (leaf, Left only, Right only, Both)

1 possibility for children: Both (which could be NULL_NODE)

A dummy NULL_NODE lets you recurse to a simpler base case while avoiding null pointer exceptions

```java
public class BinarySearchTree<T> {
    private BinaryNode root;

    public BinarySearchTree() {
        root = null;
    }

    public int size() {
        if (root == null) {
            return 0;
        }
        return root.size();
    }

    class BinaryNode {
        private T data;
        private BinaryNode left;
        private BinaryNode right;

        public int size() {
            if (left == null && right == null) {
                return 1;
            } else if (left == null) {
                return right.size() + 1;
            } else if (right == null) {
                return left.size() + 1;
            } else {
                return left.size() + right.size() + 1;
            }
        }
```

```java
public class BinarySearchTree<T> {
    private BinaryNode root;

    private final BinaryNode NULL_NODE = new BinaryNode();

    public BinarySearchTree() {
        root = NULL_NODE;
    }

    public int size() {
        return root.size();
    }

    class BinaryNode {
        private T data;
        private BinaryNode left;
        private BinaryNode right;

        public BinaryNode(T element) {
            this.data = element;
            this.left = NULL_NODE;
            this.right = NULL_NODE;
        }

        public int size() {
            if (this == NULL_NODE) {
                return 0;
            }
            return left.size() + right.size() + 1;
        }
```

Simpler

Simpler

More Trees

Comment out unused tests and uncomment as you go

Write `containsNonBST(T item)` now.

Notice the pattern: contains

- If (node is null)
  - Return something simple
- Recurse to the left
- Recurse to the right
- Combine results with this node

```java
public class BinarySearchTree<T> {
    private BinaryNode root;

    private final BinaryNode NULL_NODE = new BinaryNode();

    public BinarySearchTree() {
        root = NULL_NODE;
    }

    public boolean containsNonBST(T item) {
        return root.containsNonBST(item);
    }

    class BinaryNode {
        private T data;
        private BinaryNode left;
        private BinaryNode right;

        public BinaryNode() {
            this.data = null;
            this.left = null;
            this.right = null;
        }

        public boolean containsNonBST(T item) {
            if (this == NULL_NODE) {
                return false;
            }
            return this.data.equals(item) ||
                   left.containsNonBST(item) ||
                   right.containsNonBST(item);
        }
    }
}
```

Notice the pattern: size

- If (node is null)
  - Return something simple
- Recurse to the left
- Recurse to the right
- Combine results with this node

```java
public class BinarySearchTree<T> {
    private BinaryNode root;

    private final BinaryNode NULL_NODE = new BinaryNode();

    public BinarySearchTree() {
        root = NULL_NODE;
    }

    public int size() {
        return root.size();
    }

    class BinaryNode {
        private T data;
        private BinaryNode left;
        private BinaryNode right;

        public BinaryNode() {
            this.data = null;
            this.left = null;
            this.right = null;
        }

        public int size() {
            if (this == NULL_NODE) {
                return 0;
            }
            return left.size() + right.size() + 1;
        }
    }
}
```

Notice the pattern: height

- If (node is null)
  - Return something simple
- Recurse to the left
- Recurse to the right
- Combine results with this node

```java
public class BinarySearchTree<T> {
    private BinaryNode root;

    private final BinaryNode NULL_NODE = new BinaryNode();

    public BinarySearchTree() {
        root = NULL_NODE;
    }

    public int height() {
        return root.height();
    }

    class BinaryNode {
        private T data;
        private BinaryNode left;
        private BinaryNode right;

        public BinaryNode() {
            this.data = null;
            this.left = null;
            this.right = null;
        }

        public int height() {
            if (this == NULL_NODE) {
                return -1;
            }
            return Math.max(left.height(), right.height()) + 1;
        }
    }
```

What else could you do with this recursive pattern?

- If (node is null)
  - Return something simple
- Recurse to the left
- Recurse to the right
- Combine results with this node

- Print the tree contents
- Sum the values of the nodes
- Dump the contents to an array list
- Lots more

- In what order should we print nodes?

Binary tree traversals

- InOrder (left-to-right, if tree is spread out)
  - Left, root, right
- PreOrder (top-down, depth-first)
  - root, left, right
- PostOrder (bottom-up)
  - left, right, root
- LevelOrder (breadth-first)
  - Level-by-level, left-to-right within each level

If the tree has N nodes, what's the (worst-case) big-Oh run-time of each traversal?

```
// Print tree rooted at current node using preorder
public void printPreOrder( )   {
    System.out.println( element );          // Node
    if( left != null )
        left.printPreOrder( );              // Left
    if( right != null )
        right.printPreOrder( );             // Right
}


// Print tree rooted at current node using postorder
public void printPostOrder( ) {
    if( left != null )
        left.printPostOrder( );             // Left
    if( right != null )
        right.printPostOrder( );            // Right
    System.out.println( element );          // Node
}

// Print tree rooted at current node using inorder t
public void printInOrder( ) {
    if( left != null )
        left.printInOrder( );               // Left
    System.out.println( element );          // Node
    if( right != null )
        right.printInOrder( );              // Right
}
```

Converting the tree to an ArrayList gives an elegant solution for toString()

- Brainstorm how to write:

```
public ArrayList<T> toArrayList()
```

- Then BST toString() will simply be:

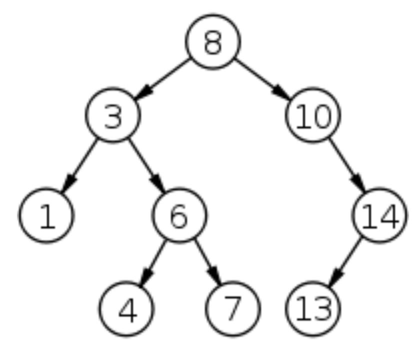
```
return toArrayList().toString();
```

Use the recursive pattern when you want to process the whole tree at once

Size(), height(), contains(), toArrayList(), toString(), etc.

What if we want an iterator (one element at a time)?

Next class



Exam 1

- Exam 1 – Day 8: 7–9 pm
  - Coverage:
    - Everything from reading and lectures, Sessions 1–7
    - Programs: Warmup, Stacks and Queues
    - Homeworks 1–2
  - Allowed resources:
    - Written part: ½ of one side of 8.5 x 11 paper
      - Goal: to let you use formulas but force you to summarize.
    - Programming part:
      - Textbook
      - Eclipse (including programs you wrote in your repos)
      - Course web pages and materials on Moodle
      - Java API documentation
    - Two previous 230 Exam 1's are available in Moodle

Exam 1 Possible Topics

- Written (50–70%):
  - Growable Arrays
  - MCSS
  - big O/θ/Ω: true/false, using definitions, limits, code analysis
  - Binary search
  - ADT/Collections
  - Choosing an ADT to solve a given problem

- Programming (30–50%):
  - Implementing an ADT using an array, nodes, or another ADT
  - Writing an efficient algorithm to solve a simple array-based problem

Exam Review

The Big Picture

- All data structures really boil down to:
  - Continuous memory (**arrays**), or
  - Nodes and pointers (**linked lists, trees, graphs**)
- Let's draw pics of each
- Then you do the questions on the back with a partner as exam review

- Then time for questions