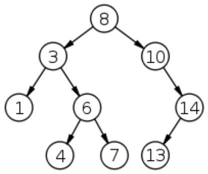


Q1-3

CSSE 230 Day 7

More BinaryTree methods
Tree Traversals

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

Announcements

- Please complete the Stacks&Queues partner evaluation in Moodle after you submit your final code.
  Due soon after you submit the project (or by Thursday night).

- Doublets is next programming assignment.
- Solve it with a partner – meet later during today's class.
- Instructor demo later too.

- Questions (Exam, Stacks & Queues, HW3)?

Move to day 6

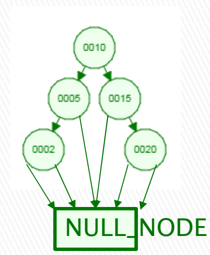
Questions?

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.

Casey Dant, 201410.

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)

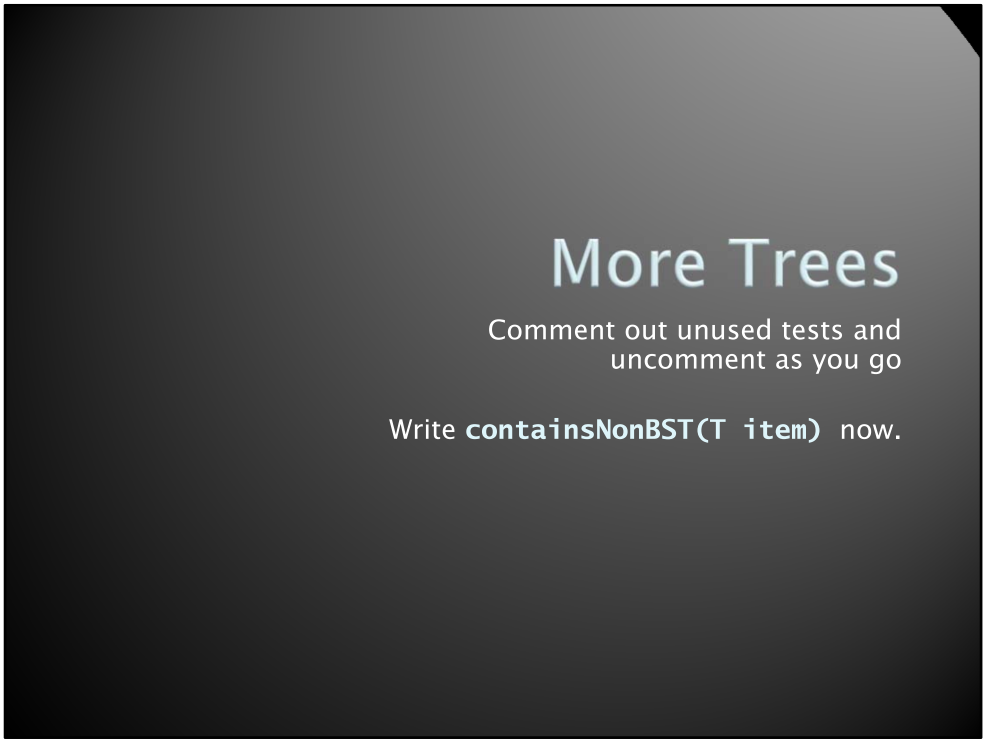
A dummy NULL_NODE lets you recurse to a simpler base case while avoiding null pointer exceptions

```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



Have students create new project for doing this. [[[See BinaryTreeInClassSolution for code.]]]
Another approach is in BinaryTreeWithNullNode.
{{CWA: I started without the null node, wrote size, pointed out how ugly it was, introduced
The null node, fixed size(), then continued to do the other methods.

Have them write contains(), then live code contains() to check.
Point: recursion is your friend. Get good at it!

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?

4-7

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

Make up a tree and show the 4 walks through examples on board, have them do quiz questions after each one on the board.
Point out level order is different!

Implement at least one of them (inorder?) as toString() in the project.
Hard to get spaces right if NULL_NODE, so practice before class.

In Binary Tree: println("Inorder Traversal:"
  printInOrder(this.root);
The write PrintInOrder in BinaryTree to begin with if (this != BinaryTree.NULL_NODE)

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

```java
// 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
}
```

O(N)
O(N) for stack frames

8

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();
```

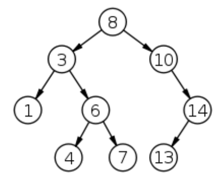
Have them sketch algorithm for toArrayList, then do it together. Use it for toString.

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



Doublets Intro