

CSSE 230 Day 7

More BinaryTree methods Tree Traversals and Iterators

After today, you should be able to...

- ... traverse trees on paper & in code
- ... implement a simple iterator for trees



SOA Hack Night

You're invited to a service-oriented architecture (SOA) hack night, led by developers from Enova International! You'll be building a small app and using IFTT to tie in Twitter, Reddit and Heroku. When we're done, you'll be a pro at integrating service APIs!

Please bring your laptop with Ruby installed.

When: Thursday, March 26, 6 – 10 p.m.

Where: Olin O257 and O259

Food Catered By: Papa John's

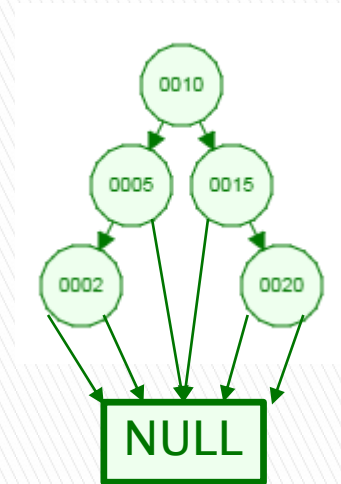
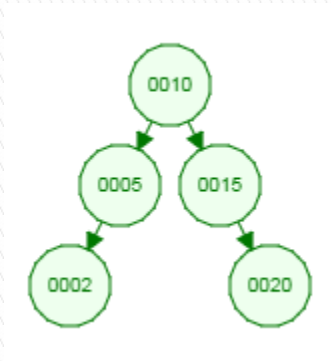
Hosted By: Zach Gallup (Sr. Software Engineer)
and Pete Brousalis (Sr. UI Engineer)

Best,

The Enova Engineering Team

▶ **Reminder:**
**Register for Hack
Night by the end
of the day!**

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

```
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;
            }
        }
    }
}
```

```
1 public class BinarySearchTree<T> {
2     private BinaryNode root;
3
4     private final BinaryNode NULL_NODE = new BinaryNode();
5
6     public BinarySearchTree() {
7         root = NULL_NODE;
8     }
9
10    public int size() {
11        return root.size();
12    }
13
14    class BinaryNode {
15        private T data;
16        private BinaryNode left;
17        private BinaryNode right;
18
19        public BinaryNode(T element) {
20            this.data = element;
21            this.left = NULL_NODE;
22            this.right = NULL_NODE;
23        }
24
25        public int size() {
26            if (this == NULL_NODE) {
27                return 0;
28            }
29            return left.size() + right.size() + 1;
30        }
31    }
32 }
```

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

```
1 public class BinarySearchTree<T> {
2     private BinaryNode root;
3
4     private final BinaryNode NULL_NODE = new BinaryNode();
5
6     public BinarySearchTree() {
7         root = NULL_NODE;
8     }
9
10    public boolean containsNonBST(T item) {
11        return root.containsNonBST(item);
12    }
13
14    class BinaryNode {
15        private T data;
16        private BinaryNode left;
17        private BinaryNode right;
18
19        public BinaryNode() {
20            this.data = null;
21            this.left = null;
22            this.right = null;
23        }
24
25        public boolean containsNonBST(T item) {
26            if (this == NULL_NODE) {
27                return false;
28            }
29            return this.data.equals(item) ||
30                left.containsNonBST(item) ||
31                right.containsNonBST(item);
32        }
33    }
34 }
```

Notice the pattern: size

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

```
1 public class BinarySearchTree<T> {
2     private BinaryNode root;
3
4     private final BinaryNode NULL_NODE = new BinaryNode();
5
6     public BinarySearchTree() {
7         root = NULL_NODE;
8     }
9
10    public int size() {
11        return root.size();
12    }
13
14    class BinaryNode {
15        private T data;
16        private BinaryNode left;
17        private BinaryNode right;
18
19        public BinaryNode() {
20            this.data = null;
21            this.left = null;
22            this.right = null;
23        }
24
25        public int size() {
26            if (this == NULL_NODE) {
27                return 0;
28            }
29            return left.size() + right.size() + 1;
30        }
31    }
32 }
```

Notice the pattern: height

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

```
1 public class BinarySearchTree<T> {
2     private BinaryNode root;
3
4     private final BinaryNode NULL_NODE = new BinaryNode();
5
6     public BinarySearchTree() {
7         root = NULL_NODE;
8     }
9
10    public int height() {
11        return root.height();
12    }
13
14    class BinaryNode {
15        private T data;
16        private BinaryNode left;
17        private BinaryNode right;
18
19        public BinaryNode() {
20            this.data = null;
21            this.left = null;
22            this.right = null;
23        }
24
25        public int height() {
26            if (this == NULL_NODE)
27                return -1;
28
29            return Math.max(left.height(), right.height()) + 1;
30        }
31    }
32 }
```


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

Binary tree traversals

- ▶ PreOrder (top-down, depth-first)
 - root, left, right
- ▶ PostOrder (bottom-up)
 - left, right, root
- ▶ InOrder (left-to-right, if tree is spread out)
 - Left, root, right
- ▶ 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
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> toArrayArrayList()
```

- ▶ Then BST toString() will simply be:

```
return toArrayArrayList().toString();
```

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

Otherwise, you'll need a loop. Examples:

- ▶ Lazy iterators (next class):
 - use a stack too.
- ▶ AVL trees (week 4):
 - use pointer to parents to move up tree and “rebalance”
- ▶ Threaded trees (HW5 and 6):
 - use pointer to next in-order nodes

What's an iterator?

- ▶ In Java, specified by `java.util.Iterator<E>`

<code>boolean</code>	<code><u>hasNext</u> ()</code> Returns <code>true</code> if the iteration has more elements.
<code>E</code>	<code><u>next</u> ()</code> Returns the next element in the iteration.
<code>void</code>	<code><u>remove</u> ()</code> Removes from the underlying collection the last element returned by the iterator (optional operation).

Binary Tree Iterators

What if we want to iterate over the elements in the nodes of the tree one-at-a-time instead of just printing all of them?