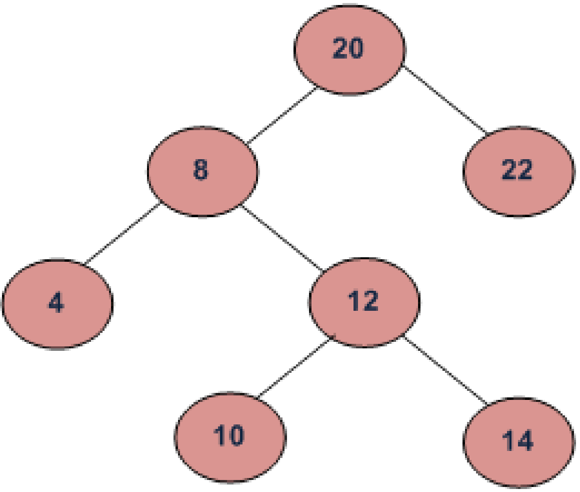


Q1

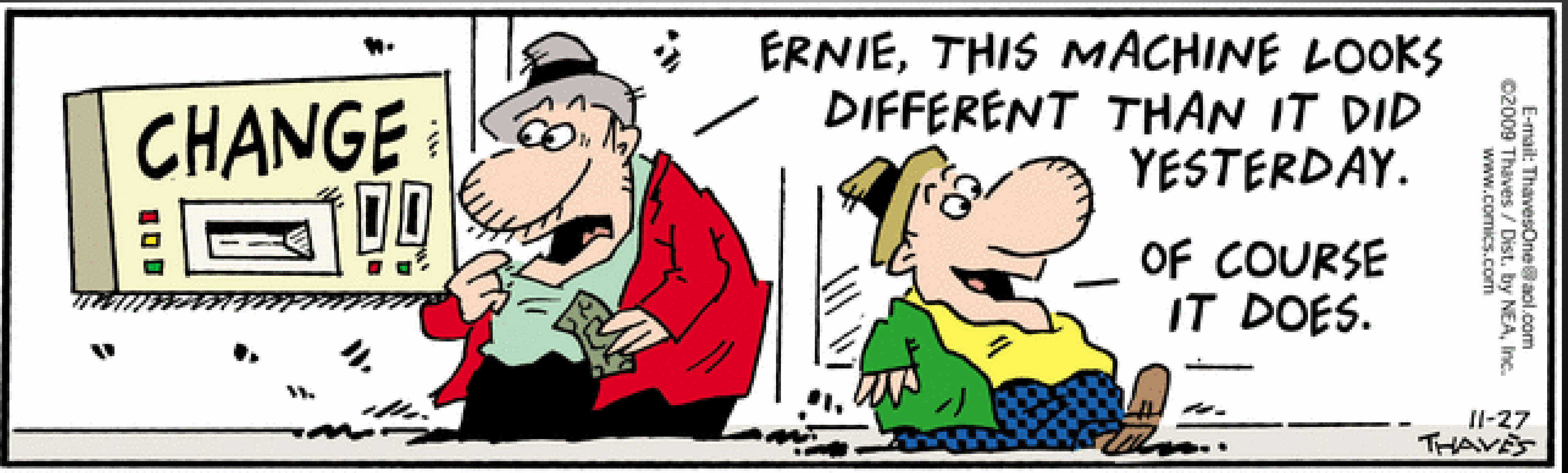
CSSE 230 Day 10

Binary Search Tree intro

BST with order properties

After today, you should be able to…
… implement insertion into a BST
… implement search (contains) in a BST
… implement deletion from a BST

Questions?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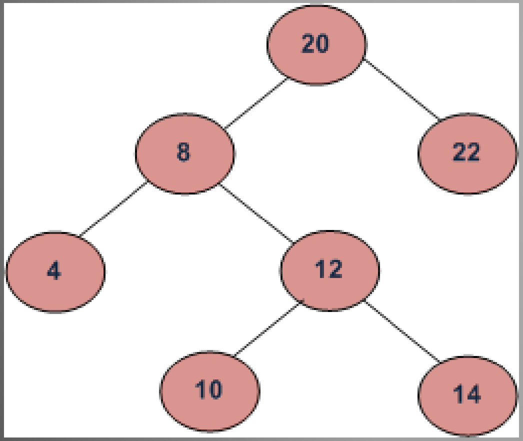
Binary Search Trees



Binary Trees that store elements in increasing order

A Binary Search Tree (BST) allows easy and fast lookup of its items because it keeps them ordered

Q2-4

Draw a "birthday BST"

- A BST is a Binary Tree T with these properties:
  1. Elements are Comparable, and non-null
  2. No duplicate elements (we implement TreeSet)
  3. All elements in T's left subtree are less than the root element
  4. All elements in T's right subtree are greater than the root element
  5. Both subtrees are BSTs
- **Advantage:** Lookup of items is O(height(T))
- What does the inorder traversal of a BST yield?

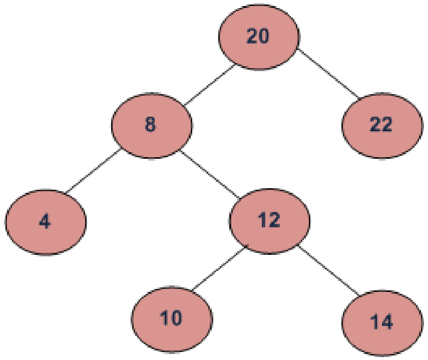
BST insert, contains, and delete are different than in a regular binary tree

Q5-8

```
public class BinarySearchTree<T extends Comparable<T>> {

 private BinaryNode root;

 public BinarySearchTree() {
   this.root = NULL_NODE; // or null;
 }
```



```
 // insert obj. If already there, return false
 public boolean insert(T obj)// yesterday

// delete obj. If not there, return false
 public boolean delete(T obj)
            // 3 cases (see text)
```

https://en.wikipedia.org/wiki/Binary_search_tree#Deletion

http://stackoverflow.com/questions/21800298/remove-a-node-in-binary-search-tree

Hibbard deletion: http://dl.acm.org/citation.cfm?id=321108

```
// Does this tree contain obj?
 public boolean contains(T obj)
```

Implementation issues, part 1 (notes from spec)

- The **recursive BinaryNode** insert() and delete() in the text return BinaryNodes. So how do the BinarySearchTree methods return Booleans?

- Could let the Boolean be a tree field. But could encapsulate better.

- Can the helper method return 2 things?
  - Create a simple composite class to hold both a boolean and a BinaryNode.
- Can you pass a parameter to the helper method and mutate it?
  - Parameters are call-by-value, so primitives can't be mutated.
  - Pass a simple BooleanContainer object so you can mutate the Boolean inside.

Implementation issues, part 2

- Modifying (inserting/deleting) from a tree should cause any current iterators to fail (throw a ConcurrentModificationException).
  - How do you detect this?
- How do you remove from an iterator?
  - Just call BST remove().
  - But throw exceptions if next() hasn't been called, or if remove is called twice in a row. (Javadoc for TreeSet iterator has details.)