CSE 12 – Basic Data Structures and Object-Oriented Design
Lecture 19

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This lecture is being recorded

Announcements

- Quiz 19 due Friday @ 12pm
- PA6 due tonight @ 11:59pm (open)
- Survey 7 due Friday @ 11:59pm
- Exam 2 – Week 8
  - Released Friday 5/21 @ 2pm
  - Due Saturday 5/22 @ 6pm
  - Topics:
    - Cumulative
    - Big topics – lectures 9 - 17
      - Big O, Big Theta run-time analysis
      - Sorting algorithms
      - Hash tables/maps

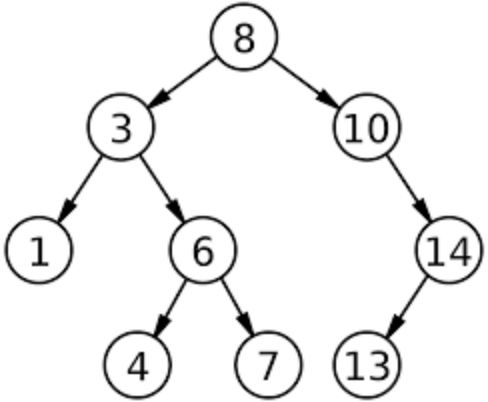
Topics

- Binary Search Trees
- Questions on Lecture 19?

Binary Search Tree

What order does PAE() traverse the tree?

```
void printAllElements(Node<K, N> n) {
  if (n == null ) return;
  System.out.println(n.key);
  printAllElements(n.left);
  printAllElements(n.right);
}
void printAllElement() {
  printAllElements(this.root);
}
```



What's the post, pre, in-order traversal of this tree?

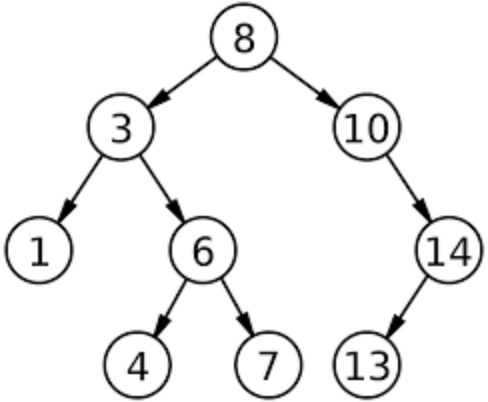
```
class Node<K,V> {
  K key;
  V value;
  Node<K,V> left;
  Node<K,V> right;
  public Node(K key, V value,
                  Node<K,V> left,
                  Node<K,V> right) {
    this.key = key;
    this.value = value;
    this.left = left;
    this.right = right;
  }
}
```

```
class BSTMap<K,V> implements OrderedDefaultMap<K,V>{
  Node<K, V> root;
  int size;
  Comparator<K> comparator;
  ...
  Node<K, V> set(Node<K, V> node, K key, V value) {
    if (node == null) {
      this.size += 1;
      return new Node<K, V>(key, value, null, null);
    }
    int comp = this.comparator.compare(node.key, key);
    if (comp < 0) {
      node.right = this.set(node.right, key, value);
      return node;
    } else if (comp > 0) {
      node.left = this.set(node.left, key, value);
      return node;
    } else {
      node.value = value;
      return node;
    }
  }

  @Override
  public void set(K key, V value) {
    if (key == null) {
      throw new IllegalArgumentException();
    }
    this.root = this.set(this.root, key, value);
  }
}
```

Binary Search Tree

- Assume the key and value are identical for this example
- set(“5”, 5);
- set(“11”, 11);
- set(“15”, 15);
- set(“12”, 12);
- What’s the picture after calling the above set() methods?



Wildcards

Hope

- Our generic class should take any type that is a subtype of `E`
- And we hope that `findFirst` can take `ArrayList` of any subtype of `E`

But

- Current generic system doesn't allow that.

```
public class WildCardsExe <E extends Person>{

  public E findFirst(ArrayList<E> list)
```

Java provides a flexible type – the wildcard – ?

```
<?> means any type
Collection<?> means Collection of any type
```

```
public class WildCardsExe <E extends Person>{

  public E findFirst(ArrayList<? extends E> list){
    if (list == null || list.size() == 0){
      return null;
    }
    return list.get(0);
  }
  public static void main(String[] args){
    WildCardsExe<Person> ref = new WildCardsExe<Person>();
    ArrayList<Person> pList = new ArrayList<Person>();
    pList.add(new Person("PC"));
    pList.add(new Person("HA"));
    System.out.println(ref.findFirst(pList));
    ArrayList<Student> sList = new ArrayList<Student>();
    sList.add(new Student("PC", 11));
    sList.add(new Student("HA", 33));
    System.out.println(ref.findFirst(sList));
  }
}
```

?: unbounded wildcard represents any subtype of E so our ArrayList is more general (it implies `? extends Object`)
? extends E : bounded wildcard represents E or any subtype of E
? super E: lower-bounded wildcard represents E or any super type of E

```
void doIt(Collection<? extends Student> data){
  for (Student s: data){
     System.out.println(s)
  }
}
```

Does the following code compile?

```
Collection<Student> data = new ArrayList<Student>();
doIt(data);
```

A. Yes
B. No

Does the following code compile?

```
Collection<Person> data = new ArrayList<Person>();
doIt(data);
```

→ compiler error

```
void doIt(Collection<? extends Student> data){
   for (Student s: data){
      System.out.println(s)
   }
}
```

Does the following code compile?

```
Collection<Student> data = new ArrayList<Student>();
doIt(data);
```

Does the following code compile?

```
Collection<Person> data = new ArrayList<Person>();
doIt(data);
```

How do we change doIt such that it will work for both situations

A. change parameter to Collection<? extends Person> data
B. change parameter to Collection<? super Student> data
C. change parameter to Collection<? super Person> data
D. change foreach loop to for (Object s: data)
E. Some combination of the above

Unbounded wildcard – '?'

? extend Animal

```
static void soundOff(Collection<?> listOfAnimals) {

    for (Animal a : listOfAnimals) {

        a.makeNoise();

    }

}

Collection<Dog> dogList = new ArrayList<Dog>();
soundOff(dogList);
```

Does this solve our problem?

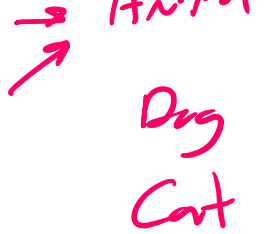
A. Yes, this code will work
B. No, this code has a compile error

addAll should accept collections that contain any type that ‘is-a’ E.

```
public abstract class AbstractCollection<E>
                implements Collection<E> {
   // Add all the elements of the argument Collection
   // to this Collection
   public boolean addAll(_______ c) {
```

? extends E

A. Collection<E>
B. Collection<?>
C. Collection<? extends E>
D. Collection<? super E>
E. More than one of these will work



```
import java.util.*;
public class SuperWildCardDemo {
  public static void main(String[] args) {
    ArrayList<String> list1 = new ArrayList<String>();
    ArrayList<Object> list2 = new ArrayList<Object>();
    list2.add("CSE");
    list2.add(12);
    list1.add("UCSD");
    add(list1, list2);
    System.out.println(list2);
  }

  public static <T> void add(ArrayList<____T____> c1, ArrayList<____T____> c2) {
    while (!c1.isEmpty())
      c2.add(c1.remove(0));
  }
}
```

What types should I fill into the blanks

A.	T	? extends T
B.	? extends T	T
C.	T	? super T
D.	? super T T	
E.	Something else	