MINI-MAX USING TREES AND THE JAVA COLLECTIONS FRAMEWORK

Lecture 16

CS2110 – Spring 2014

Important Dates.

- April 10 --- A4 due (Connect 4, minimax, trees)
- April 15 --- A5 due (Exercises on different topics, to be posted by May 28)
- April 22 --- Prelim 2.
- May 1 --- A6 due (Butterfly, graphs, search).
- May 12 --- Final exam.

Today's topics

Connect 4.

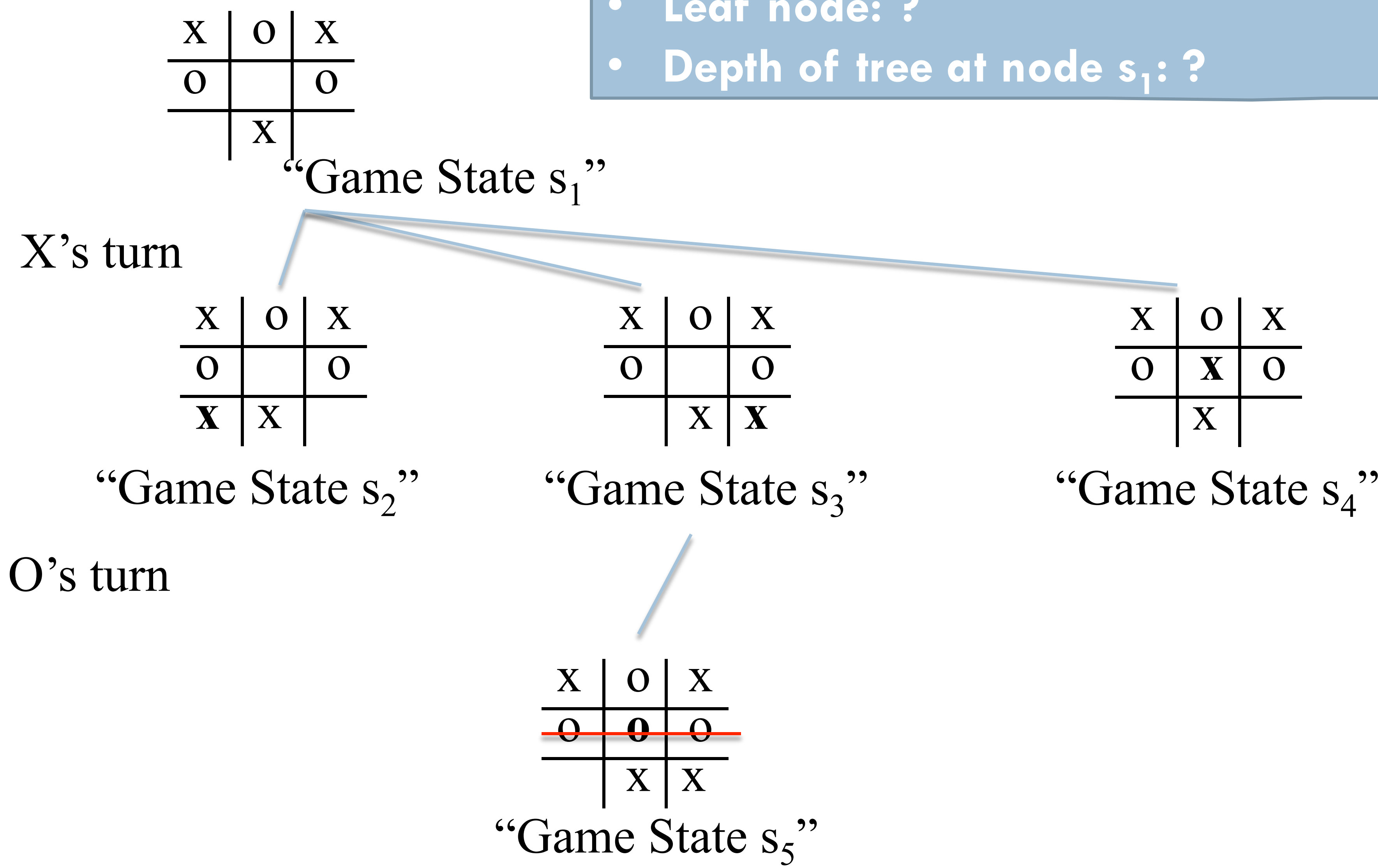
- Use of **trees** (game-tree) and **recursion** to make a Connect 4 AI.
- **Mini-max.**

Java Collections Framework

- Generic Data Types

Game State …

- Game States: s_1, s_2, … s_5
  (Also the nodes in the tree)
- Actions: edges in the tree
- Leaf node: ?
- Depth of tree at node s_1: ?



Games and Mini-Max

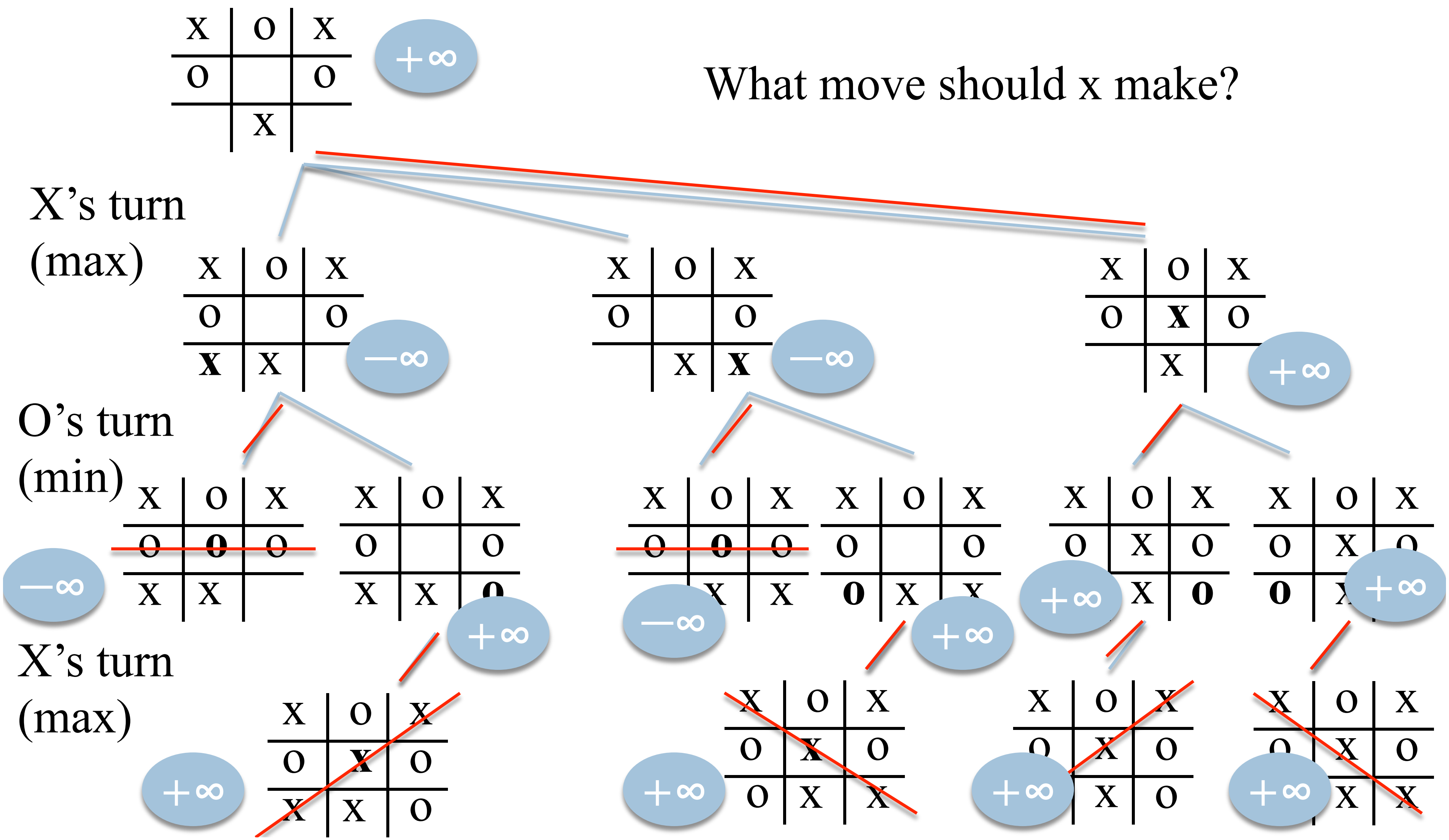
- **Mini**mizing the **max**imum possible loss.

- Choose move which results in best state
  - Select highest expected score for you

- Assume opponent is playing optimally too
  - Will choose lowest expected score for you

Game Tree and Mini-Max

What move should x make?



Properties of Mini-max

b possible moves and m steps to finish game.

- Time complexity?

  $O(b^m)$

- Space complexity?

  $O(bm)$ (depth-first exploration)

For tic-tac-toe, $b <= 9$, and $m <= 9$.

For chess, $b \approx 35$, $m \approx 100$ for "reasonable" games!!

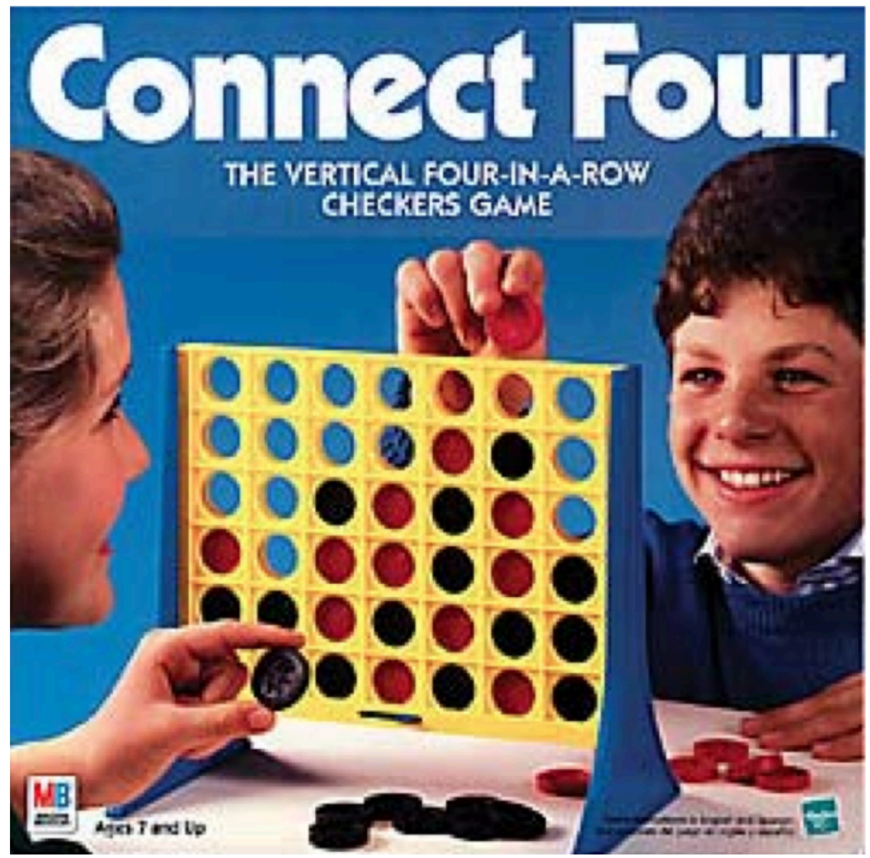
Mini-Max is used in many games!

- Stock Exchange!

Deep Blue vs. Kasparov chess matches

Deep Blue
IBM chess computer

Garry Kasparov
World Chess Champion



Robot Programming

- Can we have a robot prepare a recipe?
  - For example “Avogado”, an Italian dish.
- Natural Language → Actions.
- What do we need?
  - Parsing (to understand natural language)
  - Trees : Mini-max to figure out what actions it can do? (some of them lead to success and some of them to disaster)

Robot Programming

Today's topics

Connect 4.

- Use of **trees** (game-tree) and **recursion** to make a Connect 4 AI.
- **Mini-max.**

Java Collections Framework

- Generic Data Types

Textbook and Homework

- Generics: Appendix B
- Generic types we discussed: Chapters 1-3, 15

- Homework: Use Google to find out about the old Java **`Vector`** collection type. **`Vector`** has been "deprecated", meaning that it is no longer recommended and being phased out. What more modern type has taken over **`Vector`**'s old roles?

Generic Types in Java

- When using a collection (e.g. `LinkedList, HashSet, HashMap`), we generally have a single type T of elements that we store in it (e.g. `Integer, String`)
- Before Java 5, when extracting an element, had to cast it to T before we could invoke T's methods
- Compiler could not check that the cast was correct at compile-time, since it didn't know what T was
- Inconvenient and unsafe, could fail at runtime

- Generics in Java provide a way to communicate T, the type of elements in a collection, to the compiler
  - Compiler can check that you have used the collection consistently
  - Result: safer and more-efficient code

Example

old

```
/** Return no. of chars in the strings in
     collection of strings c. */
static int cCount(Collection c) {
  int cnt= 0;
  Iterator i= c.iterator();
  while (i.hasNext())
    cnt=  cnt + ((String)i.next()).length();
  return cnt;
}
```

new

```
/** Return no. of chars in c */
static int cCount(Collection<String> c) {
  int cnt= 0;
  Iterator<String> i= c.iterator();
  while (i.hasNext()) {
    cnt= Cnt + ((String)i.next()).length();
  return cnt;
}
```

Example – nicer looking loop

old

```
/** Return no. of chars in the strings in
  * collection c of strings. */
static int cCount(Collection c) {
  int cnt= 0;
  Iterator i = c.iterator();
  while (i.hasNext())
    cnt= cnt + ((String)i.next()).length();
  return cnt;
}
```

new

```
/** Return the number of characters in
 collection c. */
static int cCount(Collection<String> c) {
  int cnt = 0;
  for (String s: c)
    cnt= cnt + s.length();
  return cnt;
}
```

Using Generic Types

- <T> is read, "of T"
  - Example: **Stack<Integer>** is read, "Stack of Integer". Here the "T" is "Integer".
- The type annotation <T> indicates that all extractions from this collection should be automatically cast to T
- Specify type in declaration, can be checked at compile time
  - Can eliminate explicit casts
- In effect, T is a parameter, but it does not appear where method parameters appear

Advantage of Generics

- Declaring `Collection<String> c` tells us something about variable c (i.e. c holds only Strings)
  - This is true wherever c is used
  - The compiler won't compile code that violates this

- Without use of generic types, explicit casting must be used
  - A cast tells us something the programmer thinks is true at a single point in the code
  - The Java virtual machine checks whether the programmer is right only at runtime

Subtypes: Example

Stack<Integer> *not* a subtype of Stack<Object>

```
Stack<Integer> s=
              new Stack<Integer>();
s.push(new Integer(7));
// Following gives compiler error
Stack<Object> t= s; …
```

But Stack<Integer> *is* a subtype of Stack (for backward compatibility with previous Java versions)

```
Stack<Integer> s =
               new Stack<Integer>();
s.push(new Integer(7));
// Compiler allows this
Stack t= s;
```

Programming with Generic Interface Types


```
public interface List<E> {
   // Note: E is a type variable
   void add(E x);
   Iterator<E> iterator();
}

public interface Iterator<E> {
   E next();
   boolean hasNext();
   void remove();
}
```

To use interface **`List<E>`**, supply a type argument, e.g. **`List<Integer>`**

All occurrences of the type parameter (**`E`** in this case) are replaced by the type argument (**`Integer`** in this case)

Generic Classes


```
public class Queue<T> extends AbstractBag<T> {
   private java.util.LinkedList<T> queue
                  = new java.util.LinkedList<T>();

   public void insert(T item) { queue.add(item); }

   public T extract()
        throws java.util.NoSuchElementException
    { return queue.remove(); }

   public void clear() { queue.clear() }

   public int size() { return queue.size(); }
}
```

Generic Classes


```
public class InsertionSort<Comparable<T>> {
    /** Sort x */
    public void sort(T[] x) {
        for (int i= 1; i < x.length; i++) {
            // invariant is: x[0..i-1] is sorted
            // Put x[i] in its rightful position
            T tmp= x[i];
            int j;
            for (j= i; j > 0 &&
                      x[j-1].compareTo(tmp) > 0; j= j-1)
                x[j]= x[j-1];
            x[j]= tmp;
        }
    }
}
```

Java **Collections** Framework

- Collections: holders that let you store and organize objects in useful ways for efficient access

- Package **`java.util`** includes interfaces and classes for a general collection framework

- Goal: conciseness
  - A few concepts that are broadly useful
  - Not an exhaustive set of useful concepts

- The collections framework provides
  - Interfaces (i.e., ADTs)
  - Implementations

JCF Interfaces and Classes

- Interfaces
  - `Collection`
  - `Set (no duplicates)`
  - `SortedSet`
  - `List (duplicates OK)`
  - `Map (i.e., Dictionary)`
  - `SortedMap`
  - `Iterator`
  - `Iterable`
  - `ListIterator`

- Classes

  `HashSet`

  `TreeSet`

  `ArrayList`

  `LinkedList`

  `HashMap`

  `TreeMap`

`interface java.util.Collection<E>`

- **public int size();** Return number of elements
- **public boolean isEmpty();** Return true iff collection is empty
- **public boolean add(E x);**
  - Make sure collection includes x; return true if it has changed (some collections allow duplicates, some don't)
- **public boolean contains(Object x);**
  - Return true iff collection contains x (uses method equals)
- **public boolean remove(Object x);**
  - Remove one instance of x from the collection; return true if collection has changed
- **public Iterator<E> iterator();**
  - Return an Iterator that enumerates elements of collection

Iterators: How “foreach” works

The notation for(Something var: collection) { … } is syntactic sugar. It compiles into this “old code”:

```
Iterator<E> _i=
                collection.iterator();
while (_i.hasNext()) {
   E var= _i.Next();
     . . . Your code . . .
}
```

The two ways of doing this are identical but the foreach loop is nicer looking.

You can create your own iterable collections

java.util.Iterator<E> (an interface)

- **public boolean hasNext();**
  - Return true if the enumeration has more elements
- **public E next();**
  - Return the next element of the enumeration
  - Throws **NoSuchElementException** if no next element
- **public void remove();**
  - Remove most recently returned element by **next()** from the underlying collection
  - Thros **IllegalStateException** if **next()** not yet called or if **remove()** already called since last **next()**
  - Throw **UnsupportedOperationException** if **remove()** not supported

Additional Methods of `Collection<E>`

public Object[] toArray()

- Return a new array containing all elements of collection

public <T> T[] toArray(T[] dest)

- Return an array containing all elements of this collection; uses dest as that array if it can

- Bulk Operations:
  - public boolean containsAll(Collection<?> c);
  - public boolean addAll(Collection<? extends E> c);
  - public boolean removeAll(Collection<?> c);
  - public boolean retainAll(Collection<?> c);
  - public void clear();

`java.util.Set<E>` (an interface)

- **`Set`** extends **`Collection`**
  - **`Set`** inherits all its methods from **`Collection`**
- A **`Set`** contains no duplicates

  If you attempt to **`add()`** an element twice then the second **`add()`** will return false (i.e. the **`Set`** has not changed)

- Write a method that checks if a given word is within a **`Set`** of words
- Write a method that removes all words longer than 5 letters from a **`Set`**
- Write methods for the union and intersection of two **`Set`**s

Set Implementations

`java.util.HashSet<E>` (a hashtable)

- Constructors
  - `public HashSet();`
  - `public HashSet(Collection<? extends E> c);`
  - `public HashSet(int initialCapacity);`
  - `public HashSet(int initialCapacity,`
    `float loadFactor);`

`java.util.TreeSet<E>` (a balanced BST [red-black tree])

- Constructors
  - `public TreeSet();`
  - `public TreeSet(Collection<? extends E> c);`
  - `...`

`java.util.SortedSet<E>` (an interface)

- SortedSet *extends* Set

For a SortedSet, the iterator() returns elements in sorted order

- Methods (in addition to those inherited from Set):
  - public E first();
    - Return first (lowest) object in this set
  - public E last();
    - Return last (highest) object in this set
  - public Comparator<? super E> comparator();
    - Return the Comparator being used by this sorted set if there is one; returns null if the natural order is being used
  - …

`java.lang.Comparable<T>` (an interface)

- `public int compareTo(T x);`

  Return a value (< 0), (= 0), or (> 0)
  - (< 0) implies `this` is before `x`
  - (= 0) implies `this.equals(x)`
  - (> 0) implies `this` is after `x`

- Many classes implement `Comparable`
  - `String`, `Double`, `Integer`, `Char`, `java.util.Date`,…
  - If a class implements `Comparable` then that is considered to be the class's *natural ordering*

java.util.Comparator<T> (an interface)

- public int compare(T x1, T x2);

  Return a value (< 0), (= 0), or (> 0)
    - (< 0) implies x1 is before x2
    - (= 0) implies x1.equals(x2)
    - (> 0) implies x1 is after x2

- Can often use a Comparator when a class's natural order is not the one you want
    - String.CASE_INSENSITIVE_ORDER is a predefined Comparator
    - java.util.Collections.reverseOrder() returns a Comparator that reverses the natural order

SortedSet Implementations

- java.util.TreeSet<E>

  constructors:

  - public TreeSet();
  - public TreeSet(Collection<? extends E> c);
  - public TreeSet(Comparator<? super E> comparator);
  - ...

- Write a method that prints out a SortedSet of words in order
- Write a method that prints out a Set of words in order

`java.util.List<E>` (an interface)

- **List** extends **Collection** items accessed via their index
- Method **add()** puts its parameter at the end of the list
- The **iterator()** returns the elements in list-order
- Methods (in addition to those inherited from **Collection**):
  - **public E get(int i);** Return the item at position i
  - **public E set(int i, E x);** Place x at position i, replacing previous item; return the previous itemvalue
  - **public void add(int i, E x);**
    - Place x at position index, shifting items to make room
  - **public E remove(int index);** Remove item at position i, shifting items to fill the space; Return the removed item
  - **public int indexOf(Object x);**
    - Return index of the first item in the list that equals x (x.equals())
  - …

List Implementations. Each includes methods specific to its class that the other lacks

- java.util.ArrayList<E> (an array; doubles the length each time room is needed)

  Constructors

  - public ArrayList();
  - public ArrayList(int initialCapacity);
  - public ArrayList(Collection<? extends E> c);

- java.util.LinkedList <E> (a doubly-linked list)

  Constructors

  - public LinkedList();
  - public LinkedList(Collection<? extends E> c);

Efficiency Depends on Implementation

- `Object x= list.get(k);`
  - O(1) time for `ArrayList`
  - O(k) time for `LinkedList`
- `list.remove(0);`
  - O(n) time for `ArrayList`
  - O(1) time for `LinkedList`
- `if (set.contains(x)) ...`
  - O(1) expected time for `HashSet`
  - O(log n) for `TreeSet`

What if you need O(1) for both?

- Database systems have this issue

- They often build "secondary index" structures
  - For example, perhaps the data is in an ArrayList
  - But they might build a HashMap as a quick way to find desired items

- The O(n) lookup becomes an O(1) operation!