Iterators & Inner Classes

Lecture 15
CS211 – Fall 2005

Announcements

- Section 8
  (W 1:25-2:15 OH 165)
  has been folded into
  Section 5
  (W 1:25-2:15 BD 140)
  - All students with W 1:25 section should meet in BD 140
- Need a hw partner?
  - Sign up after class or
  - Email Prof Schwartz

Recall: Linear Search

- First version:
  - Input was int[], used "==" to compare elements
- More generic version:
  - Input was Comparable[], used compareTo()
- Is there a still more generic version that is independent of the data structure?
  - For example, works even with Comparable[][]

Iterator Interface

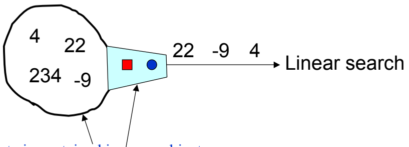
- java.util.Iterator
- Linear search can be written once and for all using Iterator interface
  - Any data structure that wants to support linear search must implement Iterator
  - We look at three ways to implement Iterator
    - Using a separate class
    - Using an inner class
    - Using an anonymous inner class

Linear Search

```
boolean linearSearch(Comparable[] a, Object v) {
   for (int i = 0; i < a.length; i++) {
      if (a[i].compareTo(v) == 0) return true;
   }
   return false;
}
```

- Relies on data being stored in a 1D array
  - Will not work if data is stored in another data structure such as a 2D array, list, stack, queue, ...
- All linear search really *needs* is:
  - Are there more elements to look at?
  - If so, get me the next element

Generic Linear Search



- Data is contained in some object
- Object has an adapter that permits data to be enumerated in some order
- Adapter has two buttons
  - `boolean hasNext()`: are there more elements?
  - `Object next()`: if so, give me a new element that has not been enumerated so far

Iterator Interface

```
interface Iterator {
   boolean hasNext();
   Object next();
   void remove(); // Optional operation
}
```

```
interface Iterable {
   Iterator iterator();
}
```

- Predefined in Java
  - java.util.Iterator
  - java.util.Iterable
- Linear search can be written using Iterator interface
- Any class that wishes to allow linear searching can do so by implementing Iterable (i.e., by providing an Iterator)

Enumeration Interface

```
interface Enumeration {
   boolean hasMoreElements();
   Object nextElement();
}
```

- You may see some code that uses the Enumeration interface instead of the Iterator interface
  - Enumeration was part of the earliest versions of Java
  - Similar functionality to Iterator (no **remove** method)
  - Iterator is preferred

Generic Linear Search

Array version

```
boolean linearSearch(Object[] a, Object v) {
   for (int i = 0; i < a.length; i++) {
      if (a[i].equals(v)) return true;
   }
   return false;
}
```

Iterator version

```
boolean linearSearch(Iterator a, Object v) {
   while (a.hasNext()) {
      if (a.next().equals(v)) return true;
   }
   return false;
}
```

How Do We Create an Iterator?

- Iterator is a Java *interface*, so we must create a class that *implements* Iterator

- To create an Iterator for class X, we can
  - Use a separate class
  - Use an inner class within X
  - Use an anonymous inner class within X

An Array Iterator (Version 1)

```
class ArrayIterator implements Iterator {
   private Object[] data;
   private int index = 0; // Index of next element

   public ArrayIterator(Object[] a)
      {data = a;}
   public boolean hasNext()
      {return (index < data.length);}
   public Object next()
      {return data[index++];}
   public void remove()
      {throw new UnsupportedOperationException();}
}
```

Using the ArrayIterator

```
String[] a = {"Hello", "world"};

Iterator iter = new ArrayIterator(a);
while (iter.hasNext()) {
  System.out.println(iter.next());
}

iter = new ArrayIterator(a);
if linearSearch(iter,"world") {
  System.out.println("found!");
}
```

Iterator Features

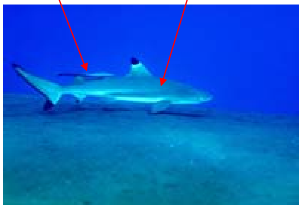
- Can create as many iterators as needed
  - Multiple iterators over same data set are fine (as long as data set isn't changed during iteration)
- Works for most data structures
  - Example: 2D arrays
    - Can keep two cursors, one for row, one for column
    - Standard orders of enumeration
      - Row-major
      - Column-major

```
class Array2DIterator implements Iterator {
   private Object[][] data;
   private int rowIndex = 0, colIndex = 0;

   public Array2DIterator(Object[][] a) { data = a; }

   public boolean hasNext() {
      while (rowIndex < data.length
      && colIndex >= data[rowIndex].length) {
         rowIndex++; colIndex = 0; //if end of row
      }
      return (rowIndex < data.length
      && colIndex < data[rowIndex].length);
   }
   public Object next() {
      if (hasNext()) return data[rowIndex][colIndex++];
      else throw new NoSuchElementException();
   }
   public void remove() {
      throw new UnsupportedOperationException();
   }
}
```

Sharks and Remoras

Iterator implementation
is like a remora

Data class is like shark

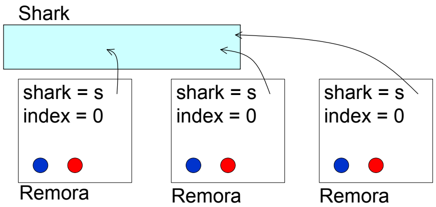


A single shark must allow many remoras to hook to it

```
class Shark implements Iterable {
  public Object[] data;
  public Shark(Object[] a) { data = a; }
  public Iterator iterator()
    {return new Remora(this);}
}

class Remora implements Iterator {
  private int index = 0;
  private Shark shark;
  public Remora(Shark s) { shark = s; }
  public boolean hasNext()
    {return (index < shark.data.length);}
  public Object next()
    {return shark.data[index++];}
  public void remove()
    {throw new UnsupportedOperationException();}
}
```

Client Code

```
String[] a = {"Hello", "world"};
Shark s = new Shark(a); //object containing data
boolean b = linearSearch(s.iterator(), "Hello");
boolean c = linearSearch(s.iterator(), "world");
boolean d = linearSearch(s.iterator(), "Bye");
```



Critique: Iterator as Separate Class

- Good
  - Shark class focuses on data
  - Remora class focuses on iteration
- Bad
  - Remora code relies on being able to access Shark variables such as data array
    - What if data were declared private?
  - Remora is specialized to Shark, but code appears outside Shark class
    - We may change Shark class and forget to update Remora
  - Clients can create Remoras without invoking iterator() method of Shark
    - Better to have language construct to enforce convention

Better: Iterator as an Inner Class

- Inner class: Java allows you declare a class within another class
- Inner classes can occur at many levels within another class
  - Member level
    - Inner class defined as if it were another field or method
  - Statement level
    - Inner class defined as if it were a statement in a method
  - Expression level
    - Inner class defined as it were part of an expression
    - Such expression-level classes are called *anonymous classes*
- Initially, we focus on member-level inner classes

Example of an Inner Class

```
class Shark implements Iterable {
  public Object[] data;
  public Shark(Object[] a) { data = a; }
  public Iterator iterator()
    {return new Remora();}
  class Remora implements Iterator {
    private int index = 0;
    public boolean hasNext()
      {return (index < data.length);}
    public Object next()
      {return data[index++];}
    public void remove()
      {throw new UnsupportedOperationException();}
  }
}
```

Client Code

```
String[] a = {"Hello", "world"};
Shark s = new Shark(a);
boolean b = linearSearch(s.iterator(), "Hello");
```

Observations

- Inner class can be declared *public*, *private*, *"package"*, or *protected*
  - Inner class name is visible accordingly
- Instances of an inner class have access to all members of containing outer-class instance
  - Even members declared *private*
- Some inner-class syntax is weird
  - Inner classes that are *public* can be instantiated by `outerObjectInstance.new InnerClass()`
  - E.g., `myShark.new Remora()`
  - Note that `new Shark.Remora()` does not work
  - If you find yourself needing this syntax, you are probably using a bad design

Inner Classes & `this`

- Keyword `this` in Remora class refers to Remora object-instance, not outer Shark object-instance
- How do we get a reference to Shark from Remora?
  - Here's one way:

```
class Shark {
  private kahuna;
  public Shark() { kahuna = this; }

  class Remora{  //inner class
    ...kahuna... //inner class can access variable
  }
}
```

  - Here's another way: `Shark.this` refers to the outer Shark object-instance

Anonymous Classes

- To permit programmers to write inner classes compactly, Java permits programmers to write anonymous classes
  - Class does not have a name
  - Must be instantiated at the point where it is defined

Anonymous Class Example

```
class Shark implements Iterable {
  public Object[] data;
  public Shark(Object[] a) { data = a; }
  public Iterator iterator() {
    return new ~~Remora();~~
  ~~}~~
  ~~class Remora implements~~ Iterator {
    private int index = 0;
    public boolean hasNext()
      {return (index < data.length);}
    public Object next()
      {return data[index++];}
    public void remove()
      {throw new UnsupportedOperationException();}
  }
}
```

Anonymous Class Example

```
class Shark implements Iterable {
  public Object[] data;
  public Shark(Object[] a) { data = a; }
  public Iterator iterator() {
    return new Iterator {
      private int index = 0;
      public boolean hasNext()
        {return (index < data.length);}
      public Object next()
        {return data[index++];}
      public void remove()
        {throw new UnsupportedOperationException();}
    };
  }
}
```

Anonymous-Class Properties

- An anonymous class is an inner class with the usual class body, but
  - No class name
  - No access specifier (i.e., no *public*/*private*/*protected*)
  - No constructor
  - No explicit use of *extends* or *implements*
    - It either extends one class or implements one interface

```
new classOrInterfaceName {...body...}
```

Anonymous Class Examples

- To specify an anonymous class (call it A) that extends class P
  - `new P { ... };      //create instance of A`
  - `new P(42) { ... }; //calls different P-constructor`
  - `P x = new P { ... }; //assignment`
- To specify an anonymous class (call it A) that implements interface I
  - `new I { ... }       //create instance of A`
  - `I y = new I { ... }; //assignment`
- Anonymous class can override methods of superclass P or implement interface methods of I
- All other methods and fields are effectively private
  - Because there is no way to invoke them from outside!

Enhanced for-loop

- As of Java 5, a for-loop works with
  - Any array type
  - Anything that implements the Iterable interface

Iterator version

```
boolean linearSearch(Iterator a, Object v) {
   while (a.hasNext())
      {if (a.next().equals(v)) return true;}
   return false;
}
```

Iterable version

```
boolean linearSearch(Iterable b, Object v) {
   for (Object x: b)
      {if (x.equals(v)) return true;}
   return false;
}
```

Conclusions

- Iterator interface allows one to write generic code
  - Works on data collections without regard to type of elements or data structure
- Inner classes are the best way to write an Iterator
- The for-each construct (i.e., enhanced for-loop) makes for more compact code, but
  - Cannot use if need access to array indices, for instance
  - Cannot use if need to use remove-operation of Iterator