

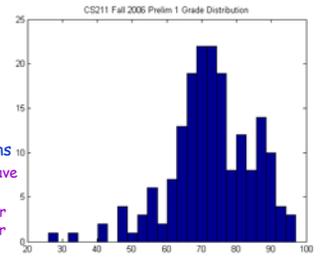


Iteration & Inner Classes

Lecture 15
CS211 - Fall 2006

Announcements

- Prelim information
 - Mean: 72.7
 - StDev: 11.9
 - Median: 72
- Some preliminary observations
 - A single method can have *multiple* stack frames
 - List problem was easier to do iteratively rather than recursively
 - Inheritance was hard



More Announcements

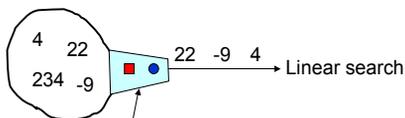
- Prelims can be picked up in 360 Upson
 - M-F, 10:00am-noon and 2:00pm-4:00pm
- Prelim regrade requests are due by Friday
 - We look at entire exam
 - Grade may go up or may go down
- ACSU General Meeting
 - Wed, October 18th, 5pm
 - Speaker is a manager from Amazon.com and he will discuss issues with large scale websites
- ACSU Programming Contest
 - Sat, October 21, 1-5pm
 - Prizes include 3 DS Lites, 3 PSPs and 3 iPod shuffles
 - Students of all skill levels should participate
 - More info on the ACSU website (acsu.cornell.edu)
- Pizza will be served at both events

Recall: 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

Goal: 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

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[][]`
- In other words, how should we *iterate*?
 - Goal: perform some action on *each item* in a collection

Strategy I: Copy to an Array

- Copy the entire collection into an array
 - Then iterate over the array
- Good
 - Straightforward to implement
- Bad
 - Can involve a lot of copying
 - A lazy method might be better
- Alternate version: Provide an array-like interface
 - numItems()
 - getItem(int i)
- Bad
 - It can be expensive to determine the i^{th} item
 - It doesn't always make sense to refer to the i^{th} item in a collection

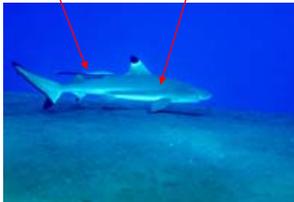
Strategy II: Iteration-State as Part of Collection

- The collection itself keeps track of iteration
 - Implies need for methods equivalent to
 - void resetIteration()
 - boolean hasNext()
 - Object getNext()
- Bad
 - Just one iteration active at a time
 - Makes it hard to share the collection

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

Strategy III: Iterator as a Separate Object

- Create an Iterator object
 - It maintains the state of the iteration
- Java provides an interface (java.util.Iterator) for this purpose
- Good
 - Can have multiple iterator objects associated with one collection
 - Standard interface for all iterations
- Bad
 - The iterator object has to know a lot about the internal structure of the collection
 - We'll see how to use inner classes to fix this

Iterator Interface

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

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

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

Iterable Interface

- Java also provides a standard interface (`java.lang.Iterable`) for anything that can be iterated

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

- An object that implements `Iterable` can be used in an `enhanced for-loop` (later in lecture)

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 it, Object v) {
    while (it.hasNext()) {
        if (it.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 () {
        if (this.hasNext()) return data[index++];
        else throw new NoSuchElementException();
    }
    public void remove () {
        throw new UnsupportedOperationException();
    }
}
```

Using the ArrayIterator

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

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

// Searching
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();
    }
}

```

Code for Sharks and Remoras

```

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 () {
        if (hasNext()) return shark.data[index++];
        else throw new NoSuchElementException();
    }
    public void remove () {throw new UnsupportedOperationException();}
}

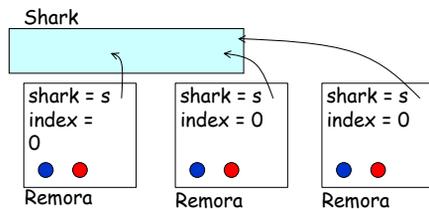
```

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

Anonymous Class Example

```
class Shark implements Iterable {
    private 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 () {
                if (hasNext()) return data[index++];
                else throw new NoSuchElementException();
            }
            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